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OPERATING AND INSTRUCTION MANUAL

MODEL VM-204 S-1045

300 MICROVOLTS

PHASE ANGLE VOLTMETER

NORTH ATLANTIC
industries, inc.

OPERATING AND INSTRUCTION MANUAL

MODEL VM-204 S-1045

300 MICROVOLTS

PHASE ANGLE VOLTMETER

NORTH ATLANTIC INDUSTRIES, INC.
Plainview New York

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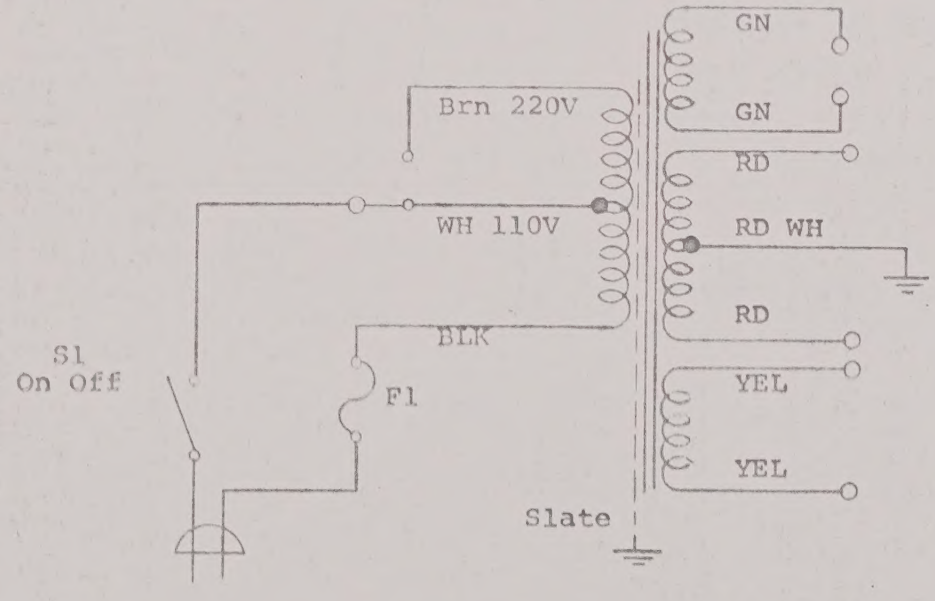
MANUAL CHANGE

TYPE 200 PHASE ANGLE VOLTMETERS

All Phase Angle Voltmeters above Serial No. 2560, may be operated from either a 110 Volt or 220 Volt, 50 to 400 cycle source. Correct operating voltage as wired at the factory is indicated on the rear panel of each instrument.

To convert from one line voltage source to the other, it is necessary to rewire the Primary of the Power Transformer. (See schematic below.) All connections are located on terminal strip in bottom left hand corner of chassis near Power Transformer.



CAUTION: Be sure to change value of fuse. For 110V operation use lamp; For 220V operation use 1/2 amp.

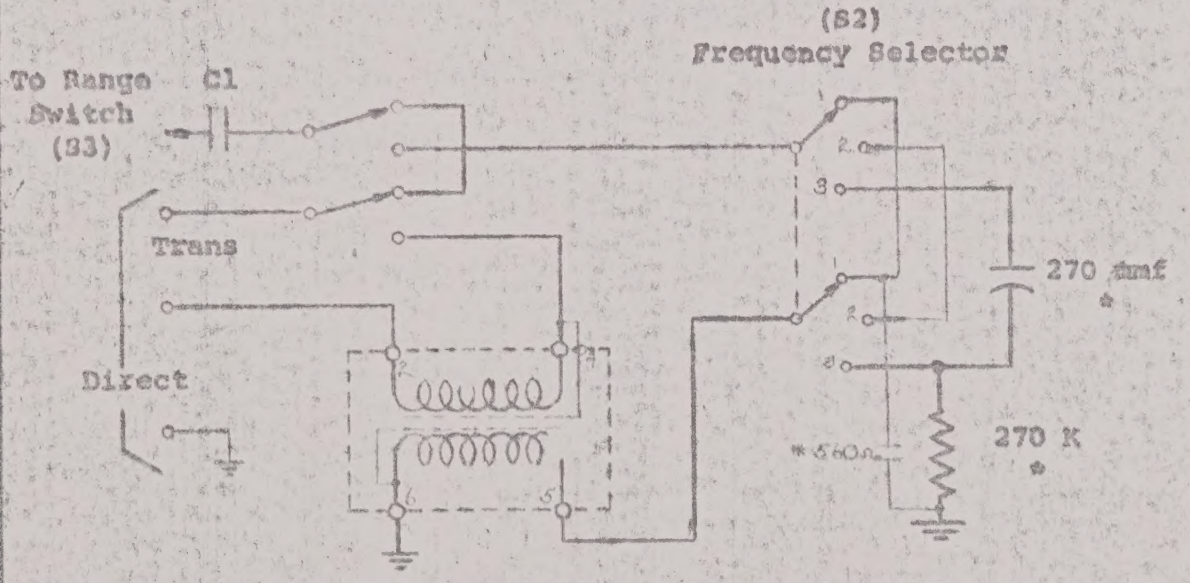
ADDENDUM 101

INSTRUCTION MANUAL SUPPLEMENT

VM-204 WITH SIGNAL ISOLATION IN/OUT SWITCH

Modification of the Signal Channel Input Direct/Transformer switching circuit has been made to compensate for transformer characteristics at higher frequencies. The diagram below reflects changes made to the schematic as shown on Page 5.4 of the Manual.

At Position 3, a typical compensating circuit has been shown for operation at 10kc. A similar configuration may also appear at Position 2 for any frequency above 2kc. Typically, Position 1 will be 400~ operation and will require the capacitive shunt as indicated. All values are nominal only and will be selected at test for optimum performance.



* Nominal Value

SUPPLEMENT

FOR

INSTRUCTION MANUAL

FREQUENCY TRIM POTENTIOMETERS

As will be noted, the frequency trim pot or pots normally mounted on the rear or bottom of the voltmeters are mounted conveniently on the front panel. These screw-driver slotted potentiometers may be ajusted through the panel bushings marked "TRIMS."

NOTE: Where two or three frequency units are concerned, the marking becomes R71-1, R71-2, and R71-3 respectively. For operation of those frequency trims, refer to operation manual.

INSTRUCTION MANUAL SUPPLEMENT

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The following list contains those components which have been changed in all instruments after Serial No. 5555. In some cases, the change involves only a North Atlantic Part Number change.

Designation	Description	NAI Part No.
C-	Capacitor, 4uf, 200V	802245
C4	Capacitor, .047uf, 200V	802395
C23	Capacitor, .1uf, 400V	802220
R9	Resistor, 6.85K	801474
R10	Resistor, 2.16K	801475
R11	Resistor, 684Ω	801476
R12	Resistor, 216Ω	801477
R13	Resistor, 68.4Ω	801478
R14	Resistor, 31.6Ω	801479
CR1,CR2,CR3,CR4	Diode, 1N3069	802924
C50,C51,C52,C53	Capacitor, Fixed, 160uuf, 500V, ±5%	802309

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The following items replace those listed in the standard replacement parts list in all instruments after S/N 6000.

Knob, Medium Pointer, 3 required, NAI #201719-1

Knob, Medium Round, 1 required, NAI #201722

Phase Dial Assembly -

White markings, 1 required, NAI #500499

Black markings, 1 required, NAI #500498

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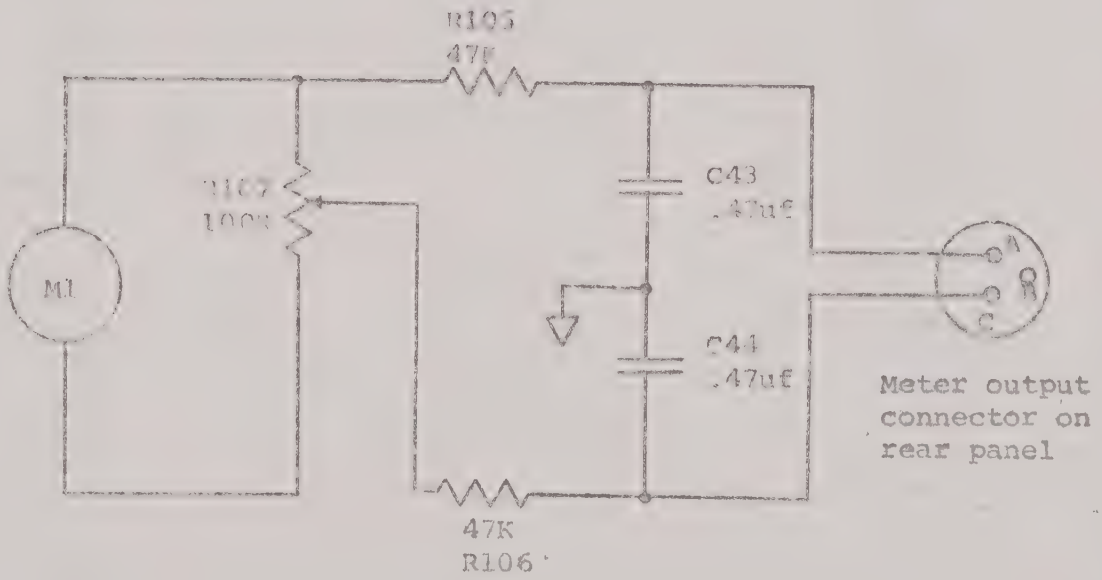
INSTRUCTION MANUAL SUPPLEMENT

VM-204

METER OUTPUT GAIN



This instrument includes the circuit shown above, which will control the DC output level as taken from across the meter in the instrument.

R105,R106	Resistor, Fixed, 47K, 1/2W, ±10%	800087
R107	Potentiometer, 100K	800005
C43,C44	Capacitor, Fixed, .47uf, 50V, ±10%	802244

Supplement Sheet No. 140
10/5/65

SPECIFICATIONS

General:	The models covered by this specification are three frequency units in the range of 30 cps to 10kc. The frequency adjust knob on the front panel of the instrument and the nameplate identify the frequencies of operation.
Voltage Range:	Full-Scale Reading: 300 microvolts to 300 volts in 13 separate ranges.
Frequency Range:	Response for phase-sensitive positions is at frequency indicated by the frequency adjust switch (see also Harmonic Rejection). For standard voltmeter operation, response from 10 cps to 50kc when used on broadband. When used as frequency sensitive voltmeter response is that of selective filters.
Frequency Response:	± 2%, 20 cps to 35kc.
Accuracy at Frequency of Operation: (400~, 800~)	±2% as a voltmeter. ±3% of full scale degrees as a phase angle voltmeter using E cos θ characteristic. (See Page 9, Table II, of Application Notes) 1^{O} calibrated phase shifter.
Phase Resolution:	$.05^{O}$ at 5:1 full scale overload.
Signal Input Impedance:	10 megohms resistive, shunted by 40uuf capacity. (When used with shielded isolation transformer for balanced input - 300k approximately at 400 cps, 1.0 meg. approximately at resonance.)
Input D.C. Voltage Level:	D.C. levels may be applied without affecting performance, such that the peak value of the combined A.C. and D.C. voltages shall not exceed 1000V in the signal input and 600V in the reference input.
Reference Input:	100K .25 volts minimum (1.25 volts minimum for units with reference isolation transformer). May be varied from 0.2 to 2.0 times redline voltage.

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Frequency Selector:	Determines frequency of operation of selective filters and phase networks.
Calibration:	Zero center voltmeters read RMS of sine wave. Line or voltage scales 3-0-3 and 10-0-10 reads E cos θ (angle between signal and reference as phase angle meter). Phase Angle Dial calibration 0^{o} to 90^{o} in 1^{o} divisions. Four position Quadrant Selector.
Overload:	Overload alarm lamp set at 5 x full scale voltage.
Power:	115V or 230V ± 10%, 60-400 cps. Approximately 60 watts at 60 cps. 115V fused @ 1.0A 230V fused @ .5A
Noise:	Less than 5 microvolts for short circuit input. Less than 50 microvolts for open circuit input.
Nulling Sensitivity:	Less than 1 microvolt in phase sensitive.
Harmonic Rejection:	Greater than 55DB.

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Overload:	Overload alarm lamp set at 5 X full scale voltage.
Power:	a) 115V or 230V ± 10%, 60-400 cps. b) 115V fused @ 1.0A c) 230V fused @ 0.5A
Noise:	a) Less than 5 microvolts for short circuit input. b) Less than 50 microvolts for open circuit input.
Nulling Sensitivity:	Less than 2 microvolts in phase sensitive modes.
Harmonic Rejection:	Greater than 55 db with filters.

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SECTION II

GENERAL DESCRIPTION

The VM-204 Phase Angle Voltmeter is a truly unique multi-functional instrument which will function as:

1. A sensitive broadband vacuum tube voltmeter.

2. A phase angle meter at any one of three rated frequencies.

3. A meter measuring in-phase signals (E cos θ), and quadrature signals (E sine θ).

4. A phase sensitive null indicator.

5. An impedance meter.

6. A power factor meter.

High input impedance (10 megohms) and voltage ranges from 300 microvolts full scale to 300 volts full scale make the instrument highly suitable for use on high impedance and low-level circuits.

Power Line Voltages and Cable

The instrument is normally wired for use on 115 volts, 60-400 cps power (230V connection available). Power consumption is approximately 60 watts at 60 cps. A three conductor power cable with a polarized connector is supplied with the instrument when both signal and reference channel have built-in isolation transformers. All other instruments receive their chassis ground through either the signal or reference inputs.

CAUTION: TO AVOID THE PITFALLS OF GROUND LOOPS DUE TO MULTIPLE POINT GROUNDS, REFER TO THE SECTION IN THE APPLICATION NOTES (APPENDIX 2) TREATING THIS SUBJECT.

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In the position marked "FUND" the instrument functions as a standard voltmeter and reads the total vector voltage of the fundamental signal of the desired frequency.

In the position marked "TOTAL" the signal filter is removed and the instrument functions as a standard voltmeter, reading the entire input signal including harmonics.

In the position marked "REF ADJ," the reference is connected to the voltmeter and can be set to a reading from 2 to 10 on the 10 scale by using the knob marked "REF ADJ." A red line is provided at mid-scale as the nominal point at which the reference level should be set.

NOTE: Phase measurements may be made with less than "Red Line Level Set." A minimum safe value, however, is a reading of 2 on the 10 scale. A setting of as large as 10 may also be considered safe for most applications.

Frequency Selector

This switch is used to select the desired frequency for "FUND" and all phase measurements.

Frequency Adjustments

These screwdriver adjustments for R71-1, R71-2, and R71-3 are located on the bottom of the instrument and are used to rezero the phase measuring dial as described under Phase Trim Adjustment, Page 2.6, this section.

As an option, R71-1, R71-2, and R71-3 can be added on the front panel.

Calibrated Phase Angle Control

This control is calibrated to read the degrees of phase shift introduced by the calibrated phase shifter within the particular quadrant selected by the "Function Selector." The actual calibration of this dial is non-linear. For this reason, should the dial ever be

removed, the procedure under Phase Dial Alignment, Paragraph IIA, Section VI, should be followed when reassembling. At 5:1 overload, a resolution of 0.1° is possible.

Phase Calibration Switch (Optional)

This instrument contains an internal "Phase Cal" switch. This is to enable the operator to simulate feeding the reference into the signal channel without physically having to make these connections for purposes of phase alignment of the two channels. A small portion of reference input is fed into the signal channel at a level equivalent to an input signal of about 3 x overload when the Reference Adjust is set at red line. The "CAL" position will automatically switch the instrument to the "90°" position. This will enable the operator to make this check independent of the position of the Range Switch or Phase Dial. The Function Switch must be in one of the phase sensitive positions.

Scale Adjust (Optional)

This instrument is equipped with a full scale adjust control which is located on the front panel and allows the full scale meter sensitivity to be adjusted as desired. A switch is included on the rear of the pot which closes at the clockwise end of the control to short out the full scale adjust control.

Meter

The meter is a zero center D. C. milliammeter calibrated to read the RMS value of a sine wave. For "STD VTVM" readings, the needle deflects to the right. For "Phase Angle VTVM" readings, the meter deflection may be either left or right.

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CAUTION: BY ITS NATURE, THE INSTRUMENT IS REQUIRED TO HANDLE INPUTS CONSIDERABLY IN EXCESS OF ITS FULL SCALE READING. THEREFORE, OVERLOAD PROTECTING CIRCUITS HAVE BEEN DESIGNED INTO THE INSTRUMENT. HOWEVER, TO PREVENT SOME UNUSUAL SITUATION FROM DRIVING THE NEEDLE HARD AGAINST THE STOPS, ALWAYS APPROACH A MEASUREMENT FROM THE LEAST SENSITIVE POSITION AND RETURN TO THIS POSITION BEFORE MAKING CIRCUIT ADJUSTMENTS.

Overload Lamp

The lamp marked "Overload" lights whenever the signal exceeds a prescribed level. This indication warns of impending amplifier overload and the attendant inaccuracies which will occur when large, saturating, signals are present. The overload indicator is factory set at approximately five-times full scale. Amplifier overload actually occurs around ten times full scale.

Power Light Fuse

The fuseholder mounted on the back of the instrument contains a standard 1 amp. cartridge fuse. (.5A for 230V connection).

Operation

The instrument, as received from the factory should indicate zero before being turned on. If it does not, reset the meter to read zero by means of the adjusting screw near the bottom of the meter face. This adjustment must be done with the power off and with the instrument in a horizontal or near horizontal position.

With the instrument plugged into the proper power source, turn the toggle switch to "ON." Allow the instrument to warm

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up about 15 minutes for stable operation. For precision phase measurements, additional time should be allowed for the reference and signal filters to reach equilibrium temperature conditions.

The VM-204 is characterized by being designed for measurements at any of three frequencies. The use of selective filters in conjunction with R-C phase shifters results in a phase shift and amplitude characteristic which is a function of the selected frequency of the input signal. A typical filter characteristic is shown in Figure 3.3.

CAUTION: BEFORE MAKING PHASE OR VOLTAGE MEASUREMENTS, REVIEW SECTION ON GROUNDING.

To Measure Voltage

1. Set the Range Switch to the appropriate scale and the Function Selector to a "TOTAL" or "FUND."

2. Connect the voltage to be measured to the signal input terminal.

3. Read the voltage from either the 0-10 scale or the 0-3 scale using the proper scale factor as determined by the Range Selector position.

   It will be noticed that with no input to the instrument, the meter needle deflects on the low ranges. This condition is normal and represents a true measurement of the stray fields capacitively coupled to the input. Shielding the input will reduce this deflection to near zero.

   Measurements made on high impedance circuits require that special attention be paid to capacitive as well as inductive pickup. Twisted and/or shielded cable will reduce the effect although the cable capacity could serve to load the source. Care must also be taken to insure that

ground loops do not exist by virtue of the signal and reference grounds which will result in erroneous readings. (See Application Notes in Appendix for a discussion of this problem.)

To Measure Phase Angle

The measurement of the phase angle of the VM-204 can be accomplished by two different techniques. "E cos 0" method will usually be more accuate with smaller angles, primarily those below 6^{o}. The calibrated phase shift method will be more accurate at greater angles, or those above 6^{o}. The accuracy obtainable may be found in Specifications in the first section of this book. The Reference Adjustment and Phase Adjustment Check following will be necessary in either case.

Reference Adjustment

1. With instrument turned on, connect the reference to the reference input.

2. Turn the Function Selector to "REF ADJ" and adjust the "REF ADJ" knob until the meter reads on the red line. (For less than red line, unit will operate. Some degraded performance will be obtained when using full overload capability.)

Phase Trim Adjustment

1. This adjustment is factory set and should seldom need to be touched except following servicing and tube replacement. Using a signal source equal to full scale on any range greater than 0.3 volts, connect the signal input into the reference channel, and adjust the reference level in accordance with the preceding.

2. Switch Frequency selector to frequency of interest.

3. a) Place Function Selector in 0^{o} position and the Phase Angle Dial at 90^{o}.

b) Place Function Selector in 90° position and the Phase Angle Dial at 90°.

c) If the meter does not read zero for both these tests, use the back panel screwdriver adjustment, R71, to provide a zero which is the best compromise for both cases. In general, once this setting is made, there is little reason to re-adjust the control unless special measurements are made such as are described later in Section III and in the appended Application Notes.

This phase rezeroing procedure will in no way affect the accuracy of the instrument.

Phase Angle Measurement Using Calibrated Phase Shifter

1. With Frequency Selector in proper position, reference adjusted to the red line, and phase shifter properly zeroed, connect the input signal to the voltmeter and use the meter scale providing a maximum reading in the "FUND" position of the Function Selector.

2. Switch the Function Selector to a suitable Phase Angle Voltmeter position (0°, 90°, 180°, or 270°), and turn the degrees dial to read a near maximum.

3. Switch the Function Selector an additional 90°. Turn the degrees dial until the meter reads zero. Switch the Function Selector to a position (0°, 90°, 180°, or 270°) which gives a meter deflection to the right. The phase angle is then the sum of the Function Selector angle plus the Phase Dial angle. This rule eliminates the possibility of ambiguity.

Phase Angle Measurement Using E cos θ Characteristic

Accurate measurements of phase angle can also be made using the E cos θ or E sin θ characteristic. Voltage

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measurements are made of the in-phase or quadrature component and of the fundamental signal (FUND position). The quotient will then be the cosine or sine of the unknown phase angle. Trigonometric tables, slide rule, or graphs included in the appended Application Notes are suitable for converting to degrees. The accuracy achievable using this technique depends upon the procedure and for that reason it is suggested that the Application Notes be reviewed before using this method.

To Measure the In-Phase and Quadrature Component of a Signal

1. With the reference level set, place Function Selector in 0^{o} position. Set the Phase Shift Dial to 0^{o}.

2. The meter now reads the in-phase component of a signal. This is also E cos θ where θ is the angle between the reference and signal.

3. Switch the Function Selector 90^{o}. The meter now reads the quadrature component or E sin θ. In general, one of these components is usually much smaller than the other and for greater accuracy, it is convenient to change the range of the instrument. This can be done until the overload lamp is lit thereby warning of an impending overload condition. This light indicates that the total signal* in the amplifier exceeds five (5) times the full scale value. Measurements under all these conditions will be most accurate if the zeroing process described in the appended Application Notes is followed.

*(Combined in-phase and quadrature)

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SECTION III

General

The block diagram of Figure 1 will serve to illustrate the principle of operation of the Phase Angle Voltmeter.

The input signal to be measured first passes directly to a cathode follower (1/2 of V1) for input signals up to .3V full scale, or by means of a thousand to one input attenuator for signals above .3V full scale. This cathode follower is coupled to the range attenuators, which in turn are connected to a second cathode follower (1/2 of V1). The output of the second cathode follower feeds the grid of V2 directly, in the total mode, or the signal channel selective filter in all other modes. Differences in the attenuation between filters for each of the three frequencies are compensated by R82-1 and R82-2. The output of the selective filter is fed to the grid of V2 in all but the total mode.

The amplifier consisting of V2 and V3 feeds the rectifier section of the voltmeter. This part of the circuit is arranged as a ring type demodulator (phase sensitive rectifier) when used as a Phase Angle Voltmeter, or as a conventional voltmeter. In both cases, heavy feedback is used around the silicon diodes and amplifier to minimize the non-linear forward characteristic of the diodes as well as the calibration shift normally associated with tube ageing.

The Reference Channel consists first of a potentiometer level control followed by a cathode follower V8. The cathode follower feeds into the reference filter which in turn goes directly into the first reference channel amplifier consisting of 1/2 of V4 and V5. This amplifier is a multi-loop feedback amplifier which provides a low impedance source for driving the second reference amplifier which is identical to the first reference amplifier. The second amplifier then drives the phase sensitive rectifier when the instrument is used as a Phase Angle Voltmeter.

Amplifier

The main amplifier consists of an input pentode V2 driving a second pentode 1/2 of V3 which in turn drives the triode section of V3.

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Local feedback around the triode section serves to provide not only a very low output impedance, but provides additional stabilization for this stage, with only a slight reduction in overall loop gain. This latter is a result of the very high input impedance which the triode presents to the preceding pentode amplifier. Gain calibration for the amplifier is accomplished by potentiometers R18 and R72. The output of the amplifier drives, in addition to the phase sensitive rectifier, an indicator I2 which is biased by means of R26 so as to light when the signal level exceeds five times the full scale meter reading. Thus, it is possible to measure very small out-of-phase signals in the presence of large non-indicating in-phase signals. Under special conditions, measurement with as much as 10 times full scale overload can be made. This type of overload will not damage the meter movement in any way.

Reference Channel

The reference channel gain is adjusted by means of level pot R33. With the Function Selector set to the "REF ADJ" position, a small signal proportional to the reference level is derived from the cathode of V4 in the first reference amplifier and fed to the input of the signal amplifier. The level is then adjusted to read approximately half scale as indicated by the red line. For measurements involving a high ratio of out-of-phase to in-phase signal it is frequently desirable to use an even greater reference level so as to minimize saturation effects in the phase sensitive rectifier itself. The scale allows an increase of 2:1 over the red line. Operation in excess of this level is not recommended except under special circumstances. The zero shift which occurs when operating above the red line reference level can easily be removed by using the Frequency Trim Controls R71-1, R71-2, of R71-3 in the manner described in Section II .

Phase Sensitive Rectifier

The phase sensitive rectifier circuit is a conventional ring demodulator. Its operation can be likened to that of a set of commutating switches. The reference signal alternately connects

one side of the meter to ground through cathode resistor R18 and then the other end on the reverse cycle of the reference. The signal is therefore synchronously rectified through the meter movement. If the reference and signal are in phase, the average value will be a maximum and the meter will read a maximum. If the signals are 90° apart, the average will be zero and no reading will result. The equation governing this is:

$$I_{meter\ (avg)} = K\ E\ \cos\theta$$

Where K = proportionality constant
E = rms of signal
θ = angle between signal and reference

Demodulator saturation effects will limit this characteristic equation to the designed levels for the instrument. Under special conditions, such as are described in the appended Application Notes, the reference level is increased to improve accuracy for high signal levels. Measurements at the quadrature null point (θ = 90 deg.) are unaffected by saturation.

The response of the phase sensitive detector is limited to signals at the reference frequency as well as to odd order harmonics. All other frequencies are rejected except for signals very near to a response frequency. Here, the meter movement will oscillate between plus and minus maximums as the two near frequencies are alternately in-phase and 180 degrees out-of-phase. Response for this type detector to odd order harmonics will never be greater (usually less depending upon phase angle), than the fundamental response multiplied by a factor of 1/n where n is the order of the harmonic. Where a signal channel filter is used, there is, of course, essentially no response to harmonics in the signals.

The effect of reference harmonics is much less important than that of signal harmonics because the harmonic content can never do more than shift the point at which the diodes start to conduct. Expressed otherwise, there is an equivalent error

in degrees which results from harmonics in the reference channel. For measurements using the phase shifter, the error can be removed by trimming. For measurements using the E cos θ characteristic that effect is small because the meter reading is a function of current integrated over an entire cycle and the small error produced by distortion has a correspondingly small effect on the total current.

When used as a standard VTVM, the phase sensitive rectifier is switched to that of a full wave rectifier. Operation is identical to that of a full wave bridge power supply in which the meter movement acts as the load.

Phase Shifter

The Phase Shifters used are RC type in which two half lattice sections are used to excite taps on a potentiometer. This type of device inherently has a non-linear change in phase shift for an input shaft rotation which results in the non-linear dial calibration used. The output of this device also varies in amplitude by a factor of 0.707. This variation causes substantially zero error in the instrument. For some instruments trimming elements are used to improve the phase shifter linearity.

Filters

The filters used in the equipment are a stabilized version of the commercial filter having the same type number.

Power Supply

The power supply furnishes a well filtered high voltage d.c. for all stages except V1 and V2 which uses, in addition, a voltage regulator. Filaments are all a.c. except for V1 and V2 which are supplied with a well filtered d.c. voltage from a bridge rectifier CR5.

SECTION IV

THEORY OF OPERATION

Differential Measurements

In making differential measurements using a transformer, there are two sources of error. One is due to capacity from either side of the primary to the high side of the secondary as shown in Figure (A). This can result in an output even if $E_1 = E_2$. This effect is minimized if a secondary shield is used, connected as shown in Figure (B).

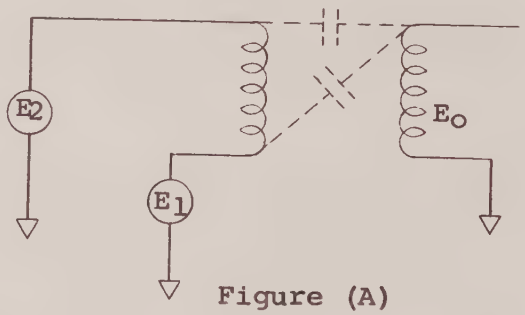

Figure (A)

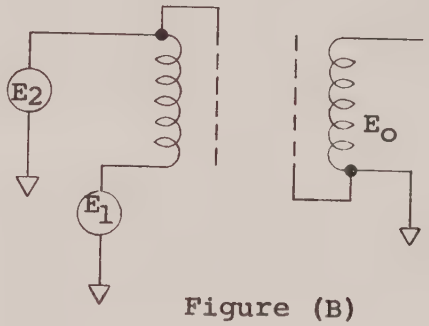

Figure (B)

The other source of error is capacity to ground, phase shifting the signal from a source with a finite source impedance as shown in Figure (C).

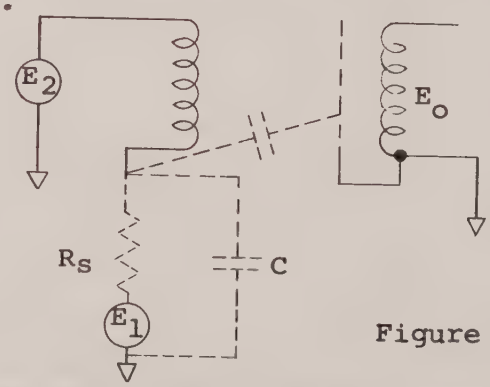

Figure (C)

This effect is minimized if a double shielded wire and a primary shield is used as shown in Figure (D). This will connect the capacity from the inner conductor to the inner shield across the transformer which, when nulled, introduces

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no error. Capacity from the inner to outer shield and capacity from the primary shield to secondary shield is across E_2. If E_2 has a low source impedance, this will introduce no error.

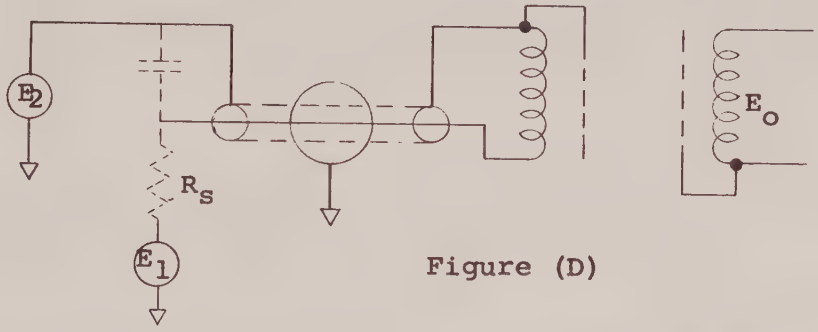
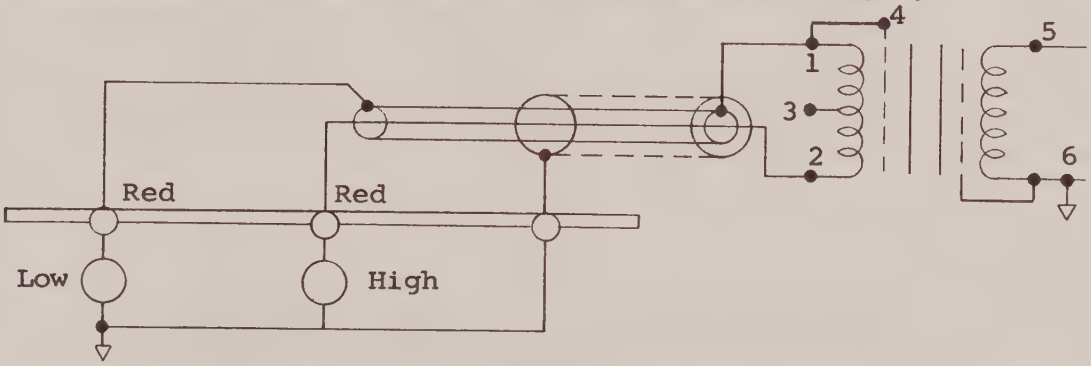


Figure (D)

Therefore, for maximum accuracy in making differential measurements, the lowest impedance source should be connected to the No. (1) pin of the signal isolation transformer (available at the left hand red binding post of the signal input terminals). Connections should be made as follows:



Instruments which have rear M. S. connectors are wired as follows:

Pin A to Pin 1 of transformer
Pin B to Pin 2 of transformer
Pin C to ground.

Input connections should be made as above.

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SECTION V

MAINTENANCE

The following section contains instructions for the general maintenance of the Phase Angle Voltmeter. Detailed alignment procedures are described in Section VI. It is recommended that alignment procedures be followed only if proper test equipment and sufficiently skilled personnel are available to perform the work.

Cover Removal

To remove top cover, remove six top screws. The bottom cover is taken off easily by removing the remaining eight bottom screws.

Tube Replacement

CAUTION: DO NOT REMOVE TUBES FROM THE VOLTMETER WHEN POWER IS APPLIED.

No circuit in the VM-204 series is critical to tube replacement. However, for maximum accuracy, the calibrations, as described in Section VI, should be checked following tube changing. In many cases, instrument malfunction may be traced to weak or faulty tubes. Before changing the setting of any of the internal adjustments, check the tubes.

Replacement of Parts

Several resistors in the voltmeter are precision components. If these resistors require replacement, use the same value and type as the original. If different values are used or components are moved, calibration or frequency response may be affected and readjustment may be required. Be careful to replace components as nearly as possible in the same position the original components occupied. Pay careful attention to wiring and do not reroute or move any of the wires. (If, for any reason, the phase shift potentiometer, R51, must be replaced in instruments up to S/N 4000, the Phase Dial must also be replaced.)

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Replacement of Diodes

Four diodes are used in the voltmeter. Two are used in the voltage measuring circuits, all four are used in making phase measurements. If replacement of the diodes is required, be careful in soldering, as the heat may damage them. Place a heat sink on each diode lead as near to the body of the diode as possible.

Note: If any of the diodes CR1, CR2, CR3, CR4, are replaced the voltmeter calibration, frequency, and phase adjustment should be checked and re-adjusted. (See Section VI.)

CAUTION:

High voltage exists at several points in the instrument. Normal precautions consistent with good practice should be taken to reduce shock hazard.

A potential shock hazard exists when ungrounded power source or ungrounded case operation is employed. Persons operating the instrument should be made aware of and take precautions against this condition.

North Atlantic Industries, Inc. cannot be held responsible for damage to person or property in the process of or as a result of maintenance, calibration, or setting up of instrument.

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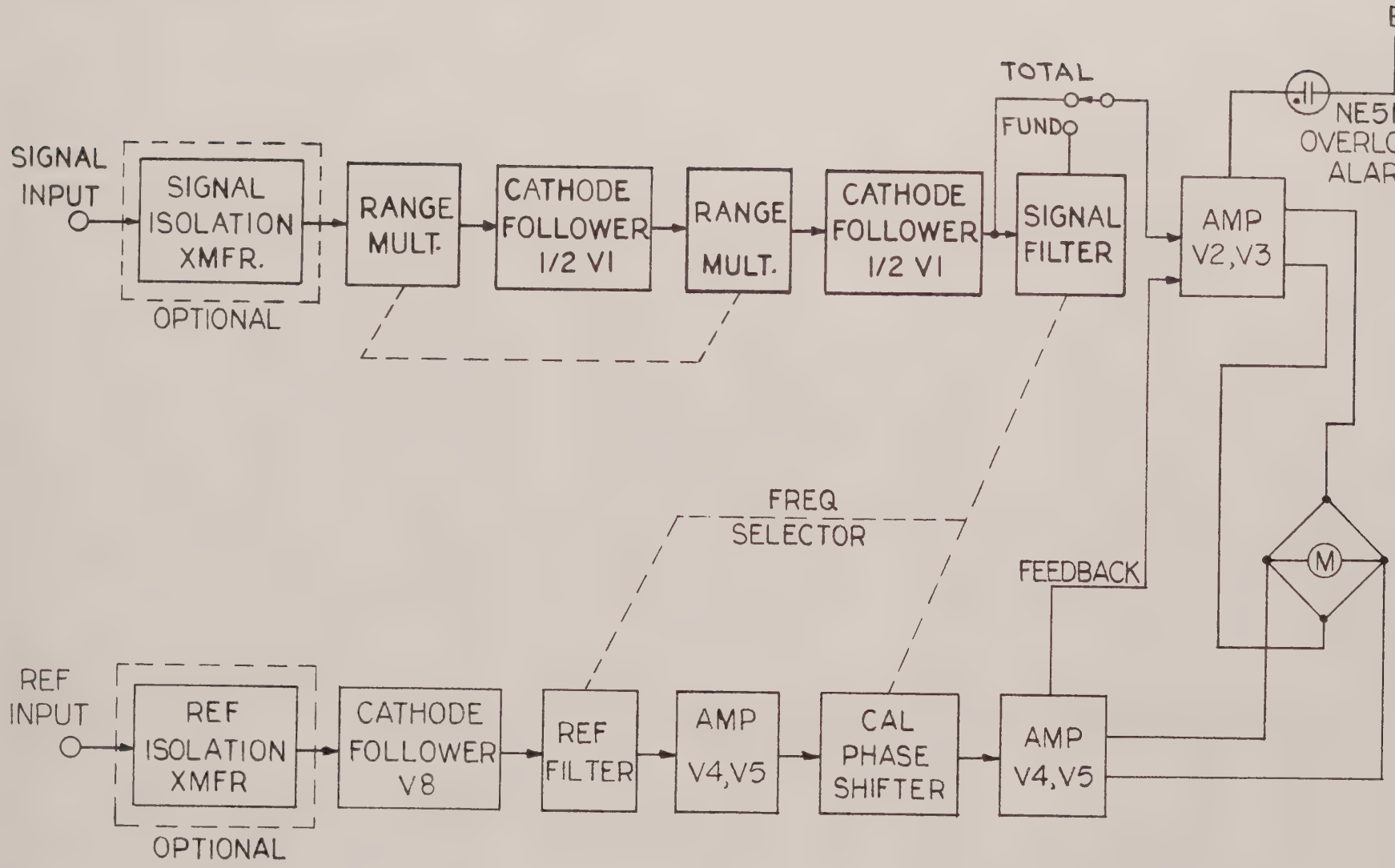
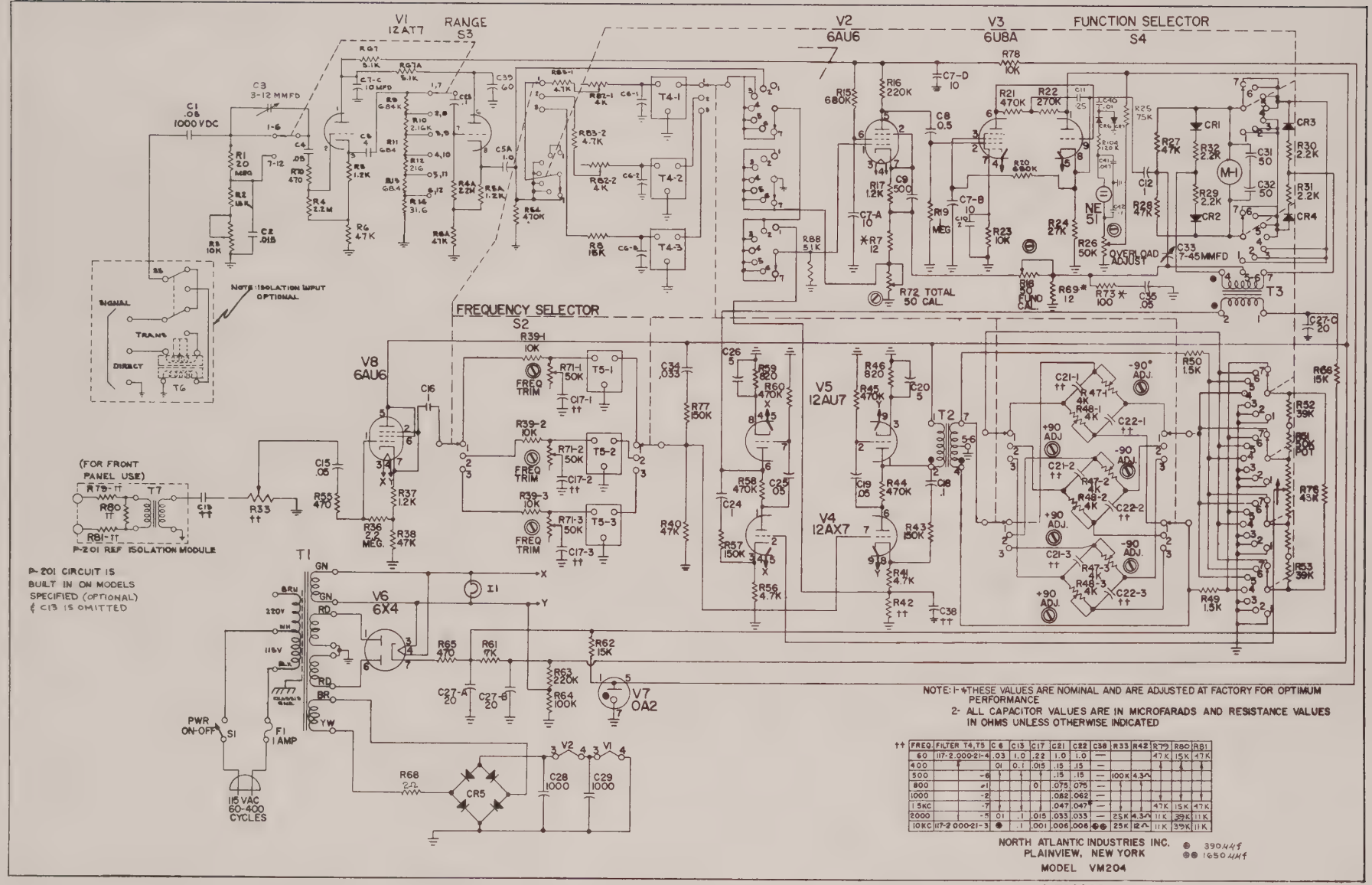


BLOCK DIAGRAM

VM204

FIG. 5.1

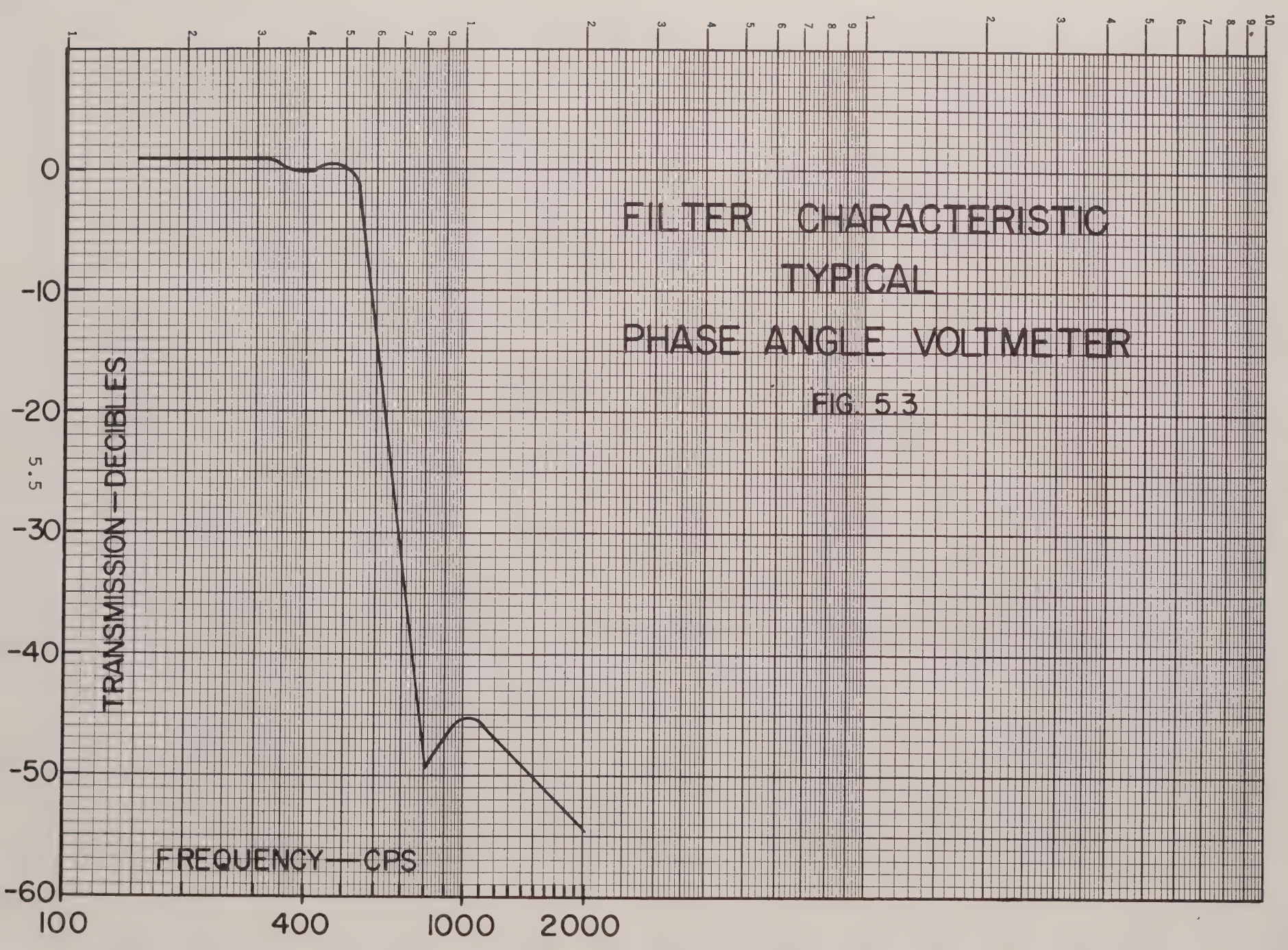


†† FREQ.	FILTER T4,T5	C6	C13	C17	C21	C22	C38	R33	R42	R79	R80	R81
60	117-2.000-21-4	.03	1.0	.22	1.0	1.0	—			47K	15K	47K
400	"	.01	0.1	.015	.15	.15	—			"	"	"
500	-8	"	"	"	.15	.15	—	100K	4.3K			
800	-11			0	.075	.075	—					
1000	-2				.062	.062	—					
1.5KC	-7				.047	.047	—			47K	15K	47K
2000	-5	.01	.1	.015	.033	.033	—	25K	4.3K	11K	39K	11K
10KC	117-2.000-21-3	●	.1	.001	.006	.006	●●	25K	2K	11K	39K	11K

● 390449
●● 1650444

5.4

Fig 5.2


FILTER CHARACTERISTIC
TYPICAL
PHASE ANGLE VOLTMETER
FIG. 5.3
TRANSMISSION — DECIBLES
0
-10
-20
-30
-40
-50
-60
FREQUENCY — CPS
100
400
1000
2000

V1 12AT7 RANGE S3

V2 6AU6

V3 6U8A FUNCTION SELECTOR S4

C1 .05 1000 VDC

C3 3-12 MMFD

R1 20 MEG

R2 15K

R3 10K

C2 .015

C4 .05

R70 470

R4 2.2M

S5

NOTE ISOLATION INPUT OPTIONAL

SIGNAL

TRANS

DIRECT

(FOR FRONT PANEL USE)

R79- T7

R80

R81-

C13 ††

R33 ††

P-201 REF ISOLATION MODULE

P-201 CIRCUIT S

RG7 5.1K

RG7A 5.1K

C7-C 10 MFD

R9 34.2K

R10 10.8K

R11 3.42K

R12 1.08K

R13 342

R14

R85 50

C5 2.0

R5 1.2K

C6 .1

R4A 2.2M

R5A 1.2K

RG6 47K

R83-1 4.7K

R82-1 4K

R83-2 4.7K

R82-2 4K

R84 15K

R54 470K

T4-1

T4-2

T4-3

R155 680K

R16 220K

C7-D 10

C8 0.5

R17 12K

C9 50

C7-A 10

*R7 12

R72 TOTAL 50 CAL.

R18 10K

R21 470K

R22 270K

R20 680K

C7-B 10

R19 1 MEG

R87 1M

C40 .002

R86 470

R23 10K

R24 27K

NE 51

R26 50K OVERLOAD ADJUST

C33 7-45MMFD

R27 47K

R28 47K

R32 2.2K

R29 2.2K

CR1

CR2

CR3

CR4

R30 2.2K

R31 2.2K

C31 50

C32 50

M-1

T3

R68 10K

R69* 5

R73* 100

C35 .05

C27-D 20

FREQUENCY SELECTOR S2

V8 6AU6

R39-1 10K

FREQ TRIM

R71-1 50K

T5-1

C17-1 ††

R39-2 10K

R71-2 50K

T5-2

C17-2 ††

R39-3 10K

R71-3 50K

T5-3

C17-3 ††

C16

C15 .05

R55 470

R37 1.2K

R36 2.2 MEG.

R38 47K

C34 .033

R77 150K

R40 47K

C26 5

R53 820

R60 470K

R58 470K

C25 .05

C24 1

R57 150K

R56 4.7K

V5 12AU7

R46 820

R45 470K

C20 5

C9 .05

R44 470K

C8 1

V4 12AX7

R43 150K

R41 4.7K

R42 ††

C38 ††

T2

C21-1 ††

R47-1 4K

R48-1 4K

C22-1 ††

C21-2 ††

R47-2 4K

R48-2 4K

C22-2 ††

C21-3 ††

R47-3 4K

R48-3 4K

C22-3 ††

-90° ADJ

+90 ADJ

30 ADJ.

R50 1.5K

R49 1.5K

R52 39K

R51 50K

R53 39K

R76 47K

R56 15K

C27-C 20

T1

GN

BRN

220V

WH

115V

BK

RD

BR

YW

CHASSIS GND

PWR ON-OFF S1

F1 1 AMP

115 VAC 60-400 CYCLES

V6 6X4

I1

X

Y

R65 470

R61 7K

R62 15K

R63 220K

R64 100K

C27-A 20

C27-B 20

V7 0A2

R68* 4.3

CR5

C28 1000

C29 1000

V2

V1

FULL SCALE ADJUST OPTIONAL

NOTE: 1- *THESE VALUES ARE NOMINAL AND ARE ADJUSTED AT FACTORY FOR OPTIMUM PERFORMANCE

2- ALL CAPACITOR VALUES ARE IN MICROFARADS AND RESISTANCE VALUES IN OHMS UNLESS OTHERWISE INDICATED

††

FREQ	FILTER T4,T5	C 6	C13	C17	C21	C22	C38	R33	R42
60	117-2.000-21-4	.03	1.0	.22	1.0	1.0	—		
400		01	0.1	.015	.15	.15	—		
500	-6				.15	.15	—	100K	4.3Ω
800	-1			0	.075	.075	—		
1000	-2				.062	.062	—		
1.5KC	-7				.047	.047	—		
2000	-5	.01	.1	.015	.033	.033	—	5K	4.3Ω
10KC	117-2 000-21-3	*	.1	.001	.006	.006	**	25K	12Ω

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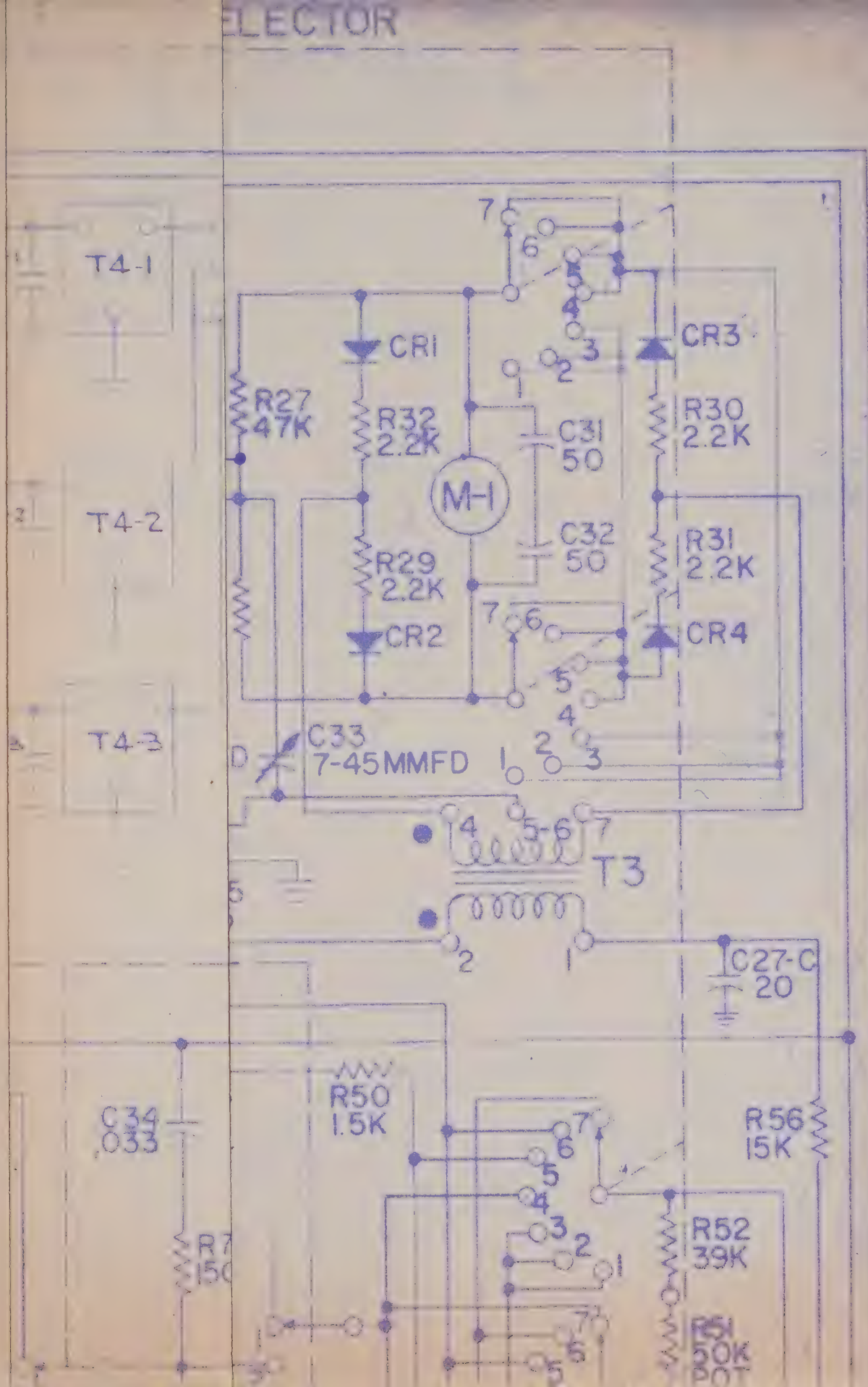
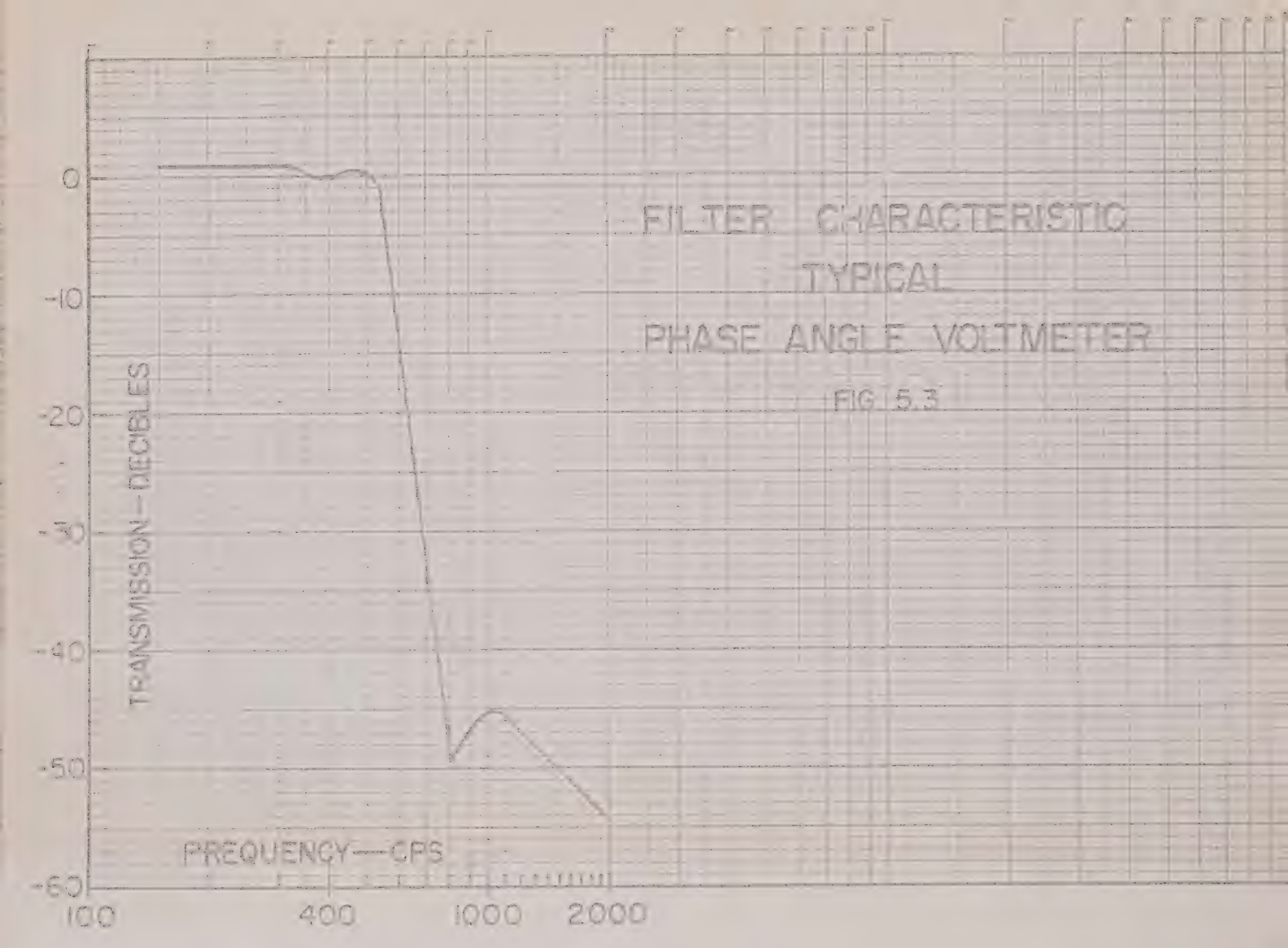
PLAINVIEW, NEW YORK
MODEL VM204


ELECTOR
T4-1
T4-2
T4-3
CR1
CR2
CR3
CR4
R27
47K
R32
2.2K
R29
2.2K
R30
2.2K
R31
2.2K
C31
50
C32
50
M-1
C33
7-45MMFD
T3
C27-C
20
C34
.033
R50
1.5K
R56
15K
R52
39K
R51
50K
POT


FILTER CHARACTERISTIC
TYPICAL
PHASE ANGLE VOLTMETER
FIG 5.3
TRANSMISSION—DECIBLES
0
-10
-20
-30
-40
-50
-60
FREQUENCY—CPS
100
400
1000
2000

SECTION VI

CALIBRATION TEST PROCEDURE

The adjustments described in this section require precision test equipment in order to achieve rated accuracy and for that reason, it is recommended that the instrument be returned to the factory, or submitted to a qualified instrument lab if this kind of re-adjustment is necessary. Reference is made to Figures 6.1 and 6.2 showing location of all adjustments (Pages 6.10 and 6.11).

I. Voltage Calibration

Equipment Required

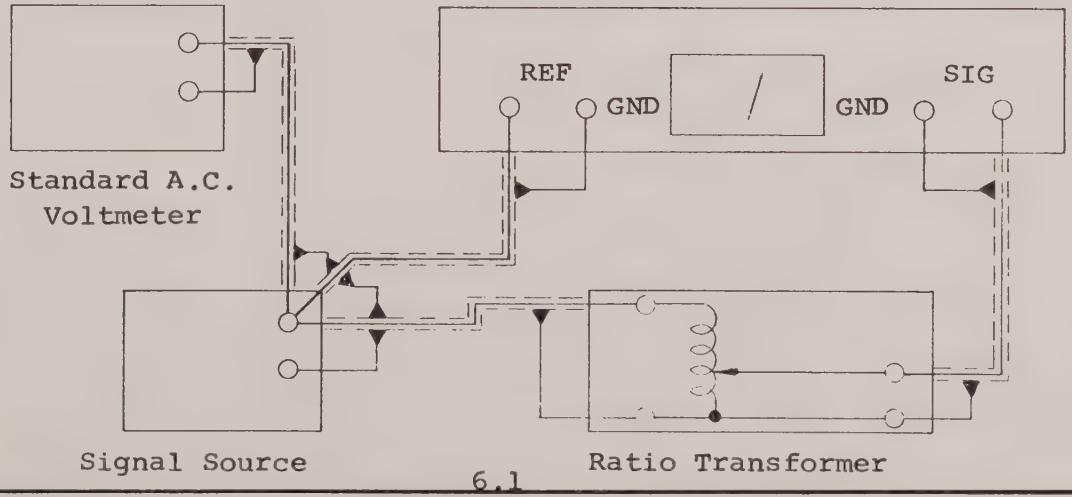
1. Variable voltage signal source capable of generating frequency of operation for the particular unit under test. Accuracy of frequency of the signal source should be ± 1/2%. Output capability at least 20 volts (e.g., Hewlett-Packard Model 200CD).

2. Standard A. C. voltmeter having accuracy of ± 3/4% of full scale reading or better, (e.g., Poly Ranger Sensitive Research Corp., Model U-88).

3. North Atlantic Industries Model RB-503 Ratio Transformer or equal.

   CAUTION: Do not use a resistive divider, which could introduce phase shift.

Connect instrumentation as shown:



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Preliminary

1. Clean face of meter with anti-static solution only.

2. Check mechanical zero.

3. Allow at least 1/2 hour warm up before making any adjustments.

Procedure

1. Set Frequency Selector to highest frequency.

2. Set output of frequency source to 10.00 volts as read on standard meter.

3. Set Function Selector switch to "REF ADJ." Adjust reference level to red line value.

4. Set Function Selector to "Fundamental."

5. Set Range Selector to 0.1.

6. Set Ratio Transformer to give output of 0.1 volts.

7. Adjust R18 (Fundamental Calibrate Pot located on top of chassis), until meter reads exactly full scale. Lock jam nut on R18.

8. Switch Function Selector to "Total" and adjust R72 (Total Calibrate Pot located on top side of chassis) for exactly full scale reading. Lock jam nut on R72.

9. Set Function Selector to "0°" and turn phase dial until meter reads exactly zero.

10. Set Range Switch to 1.0.

11. Set Ratio Transformer to 100,000 which is to provide 1.0 volts out.

12. Adjust C3 (Trimmer Capacitor under input circuit

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shield on bottom of chassis (accessible through a small hole in the shield) until meter needle moves approximately half the number of scale divisions to zero.

13. Switch Function Selector to "Fundamental" and adjust R3 (accessible through large hole in input shield, bottom of chassis) until meter pointer moves half the number of divisions between initial reading and full scale.

14. Repeat Steps 12 and 13 until meter reads exactly zero when Function Selector is in "0°" position and exactly full scale when Function Selector is in "Fundamental" position.

    Note: 1. There is considerable interaction between R3 and C3 and several adjustments may have to be made to set these controls to correct position. For frequencies above 1,000 cps the action of R3 and C3 is reversed, that is, R3 should be adjusted in Step 12 and C3 should be adjusted in Step 13. Lock R3 and glyptal C3 when this alignment is complete.

    2. This test should be performed when meter is on vertical plane.

15. Set Frequency Selector switch to next lower frequency.

16. Repeat all Steps 2 through 6.

17. Adjust R82-2 until meter reads exactly full scale. Lock jam nut on R82-2.

18. Set Frequency Selector switch to lowest frequency.

19. Repeat Steps 2 through 7.

20. Adjust R82-1 until meter reads exactly full scale.

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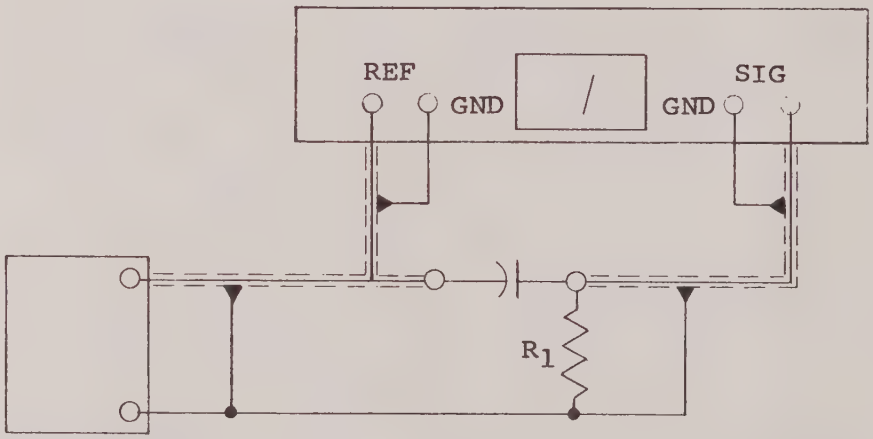
II. Phase Alignment

Step A in the following procedure will align the Phase Dial to the pot, that is, the 0^{o} and 90^{o} points on the dial will be placed as close as possible to the taps on the pot.

Step B will be the phase alignment between the signal and reference channels. This consists of injecting a precise quadrature signal into the signal channel and an in-phase signal into the reference channel with the Function Selector and Phase Dial in the "0^{o}" position.

Remove the top cover of the instrument. Connect the signal source, capacitance, and resistor as shown in the block diagram below.



SIGNAL SOURCE
f ± 1/2%

The phase alignment is made by means of adjusting R71. Step C will be the "squaring" of the Phase Bridge, that is, the precise adjustment of the "90^{o}" and "270^{o}" corners of the bridge.

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TABLE I

Operating Frequency	R_1 (Ohms)	C (MFD)	R_2 (Ohms)
60cps	120	0.01	270,000
400cps	180	0.001	390,000
800cps	91	0.001	200,000
1,000cps	91	0.001	160,000
1,500cps	47	0.001	100,000
10,000cps	91	0.0001	160,000

Note: The impedances of the above may be interpolated between frequencies shown.

CAUTION: R1, R2 should be stable type resistors; such as, carbon film. C should be low loss type capacitor; such as, polystyrene.

A. Align Phase Dial on Phase Shifter Pot R51 as Follows:

1. Turn power off.

2. Set Function Selector to any phase sensitive position.

3. Use an ohmmeter to place the wiper of R51 exactly on the CCW tap point. Loosen dial clamping screw and rotate Phase Dial until dial reading is exactly 90^{o}. Tighten clamping screw. Reconnect ohmmeter to CW tap point and rotate Phase Dial until wiper of R51 is on CW tap point. Dial should now read zero degrees. If not, reposition dial so as to achieve the best compromise reading between the two taps. For example, if the zero degree point reads low, the 90^{o} point should read high by the same amount. Fully tighten knob set screw and recheck to make sure dial has not slipped during tightening. Note this step is necessary only if dial has been moved.

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4. Turn power on. Allow 30 minute warm up before proceeding with phase alignment.

B. Detailed Field Alignment Procedure

1. Set Frequency Selector to highest frequency.

2. Set Function Selector to "Fundamental."

3. Set Range Selector to ".010."

4. Adjust voltage of signal source until approximately a full scale reading on Phase Angle Voltmeter is obtained (not less than .085.)

5. Set Function Selector to reference and adjust reference level for red line value on the meter scale.

6. Set Phase Dial at 0^{o}.

7. Set Function Selector at 0^{o}.

8. Set Range Selector to ".003" (approximately 3 x overload).

9. Adjust R71-3 (bottom of chassis) for zero reading on meter.

Note: Signal and reference channel are now phase aligned. The 0^{o} Function Selector and Phase Dial position are now calibrated.

C. Phase Bridge Alignment

1. Remove capacitor and replace with R2, as noted in Table I.

2. Set Function Selector to "Fundamental."

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3. Set Range Selector to ".010."

4. Adjust voltage of signal source to give full scale reading on meter.

5. Turn reference adjust control full counter-clockwise.

6. Set Function Selector to "Reference."

7. Adjust reference to "red line" value.

8. Set Function Selector to "90°" and Phase Dial to 0°.

9. Set Range Selector to ".003."

10. Adjust R48-3 (+90° ADJ) until meter reads exactly zero.

11. Switch Function Selector to "0°" and set Phase Dial to 90°. Meter should read zero or very close to zero. If meter does not read zero, adjust R48-3 until offset from zero reading is the same for Steps 10 and 11.

12. Set Range Switch to ".010". Set Function Selector to "180°" and Phase Dial to 90°.

13. Set Range Switch to ".003." Adjust R47-3 (-90° adjust) until meter reads zero.

14. Set Function Selector to 270° and Phase Dial to 0°. Meter should read zero or very close to zero. If meter does not read zero, adjust R47-3 until offset from zero reading is the same for Steps 13 and 14.

15. Repeat Steps in Sections B and C.

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16. Repeat procedure of alignment (all steps) until no further adjustment of R71-3, R48-3, R74-3 will improve the zero reading of any of the steps.

17. Lock jam nuts on R47-3, R48-3, and R71-3.

18. Repeat all steps for other frequencies using R48-2, R47-2, R71-2, and R48-1, R47-1, R71-1.

Note: Misalignments from zero in terms of accuracy of ± 90° points can be calculated. Smallest division on meter is equivalent to 0.38° at 3:1 overload, e.g., 1 volt input and range

III. Frequency Response Adjustment

A. Equipment Required

1. Variable voltage frequency source capable of providing frequency of operation of instrument to 50,000 cps ± 5% (e.g., Hewlett-Packard Model 400D).

2. VTVM having flat frequency response ± 1 db to 50 kc (e.g., Hewlett-Packard Model 400D).

B. Procedure

1. Connect frequency source to signal input and monitor with VTVM.

2. Set frequency of source to normal operating frequency of Phase Angle Voltmeter.

3. Set Function Selector to "Total" position.

4. Set Range Selector to .001.

5. Adjust voltage of frequency source until Phase Angle Voltmeter reads 9. Note reading of monitor VTVM.

6. Increase frequency to 50kc and set voltage of frequency source until Monitor VTVM reads the same as reading noted in Step 5.

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7. Adjust C33 (Trimmer Capacitor located on terminal board on bottom of chassis) until Phase Angle Voltmeter reads 9 minus 1/2 smallest division (approximately 1% full scale).

8. Repeat Steps 4 through 6 on .003, .3, and 1.0 ranges, and record Phase Angle Voltmeter readings. If necessary, re-adjust C33 to give best overall tolerance on all ranges.

9. Acceptable performance will be an error of ± 3% at 50kc.

IV. Overload Alarm Adjustment

This adjustment is usually required whenever the NE-51 is replaced. CAUTION: Use only NE-51. Do not use NE-51H.

A. With an input of .5 volts applied to the instrument, switch the meter range to the 0.1 volt scale.

B. Adjust R26 until the overload lamp just lights.

V. Phase Calibration Switch Adjustment

In the event that components are changed requiring the realignment of the instrument, the following procedure should be observed:

1. Realign instrument as per Calibration Test Procedure.

2. Apply an in-phase signal of the appropriate frequency (as per Calibration Test Procedure) which produces a 3:1 overload condition (i.e., 300MV on 100MV range).

3. Set Function Switch to 90^{o} and Phase Dial to 0^{o}. Instrument should read zero within specified accuracy.

4. Switch to "CAL" position. If instrument does not read same as in Step 3 above, trim R91 and R92 (R93 or R94 for second channel) with small capacitor until the same reading is produced.

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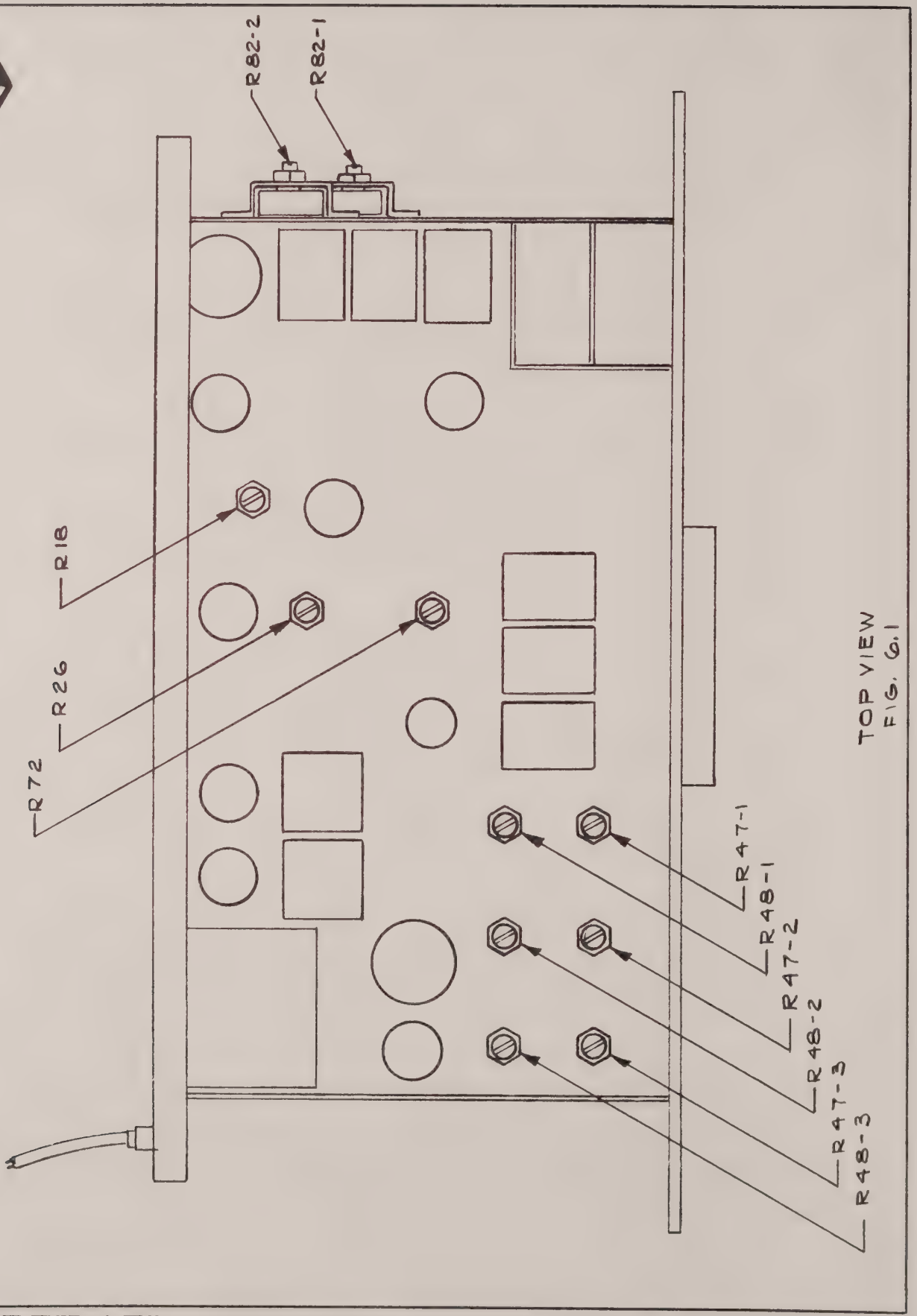
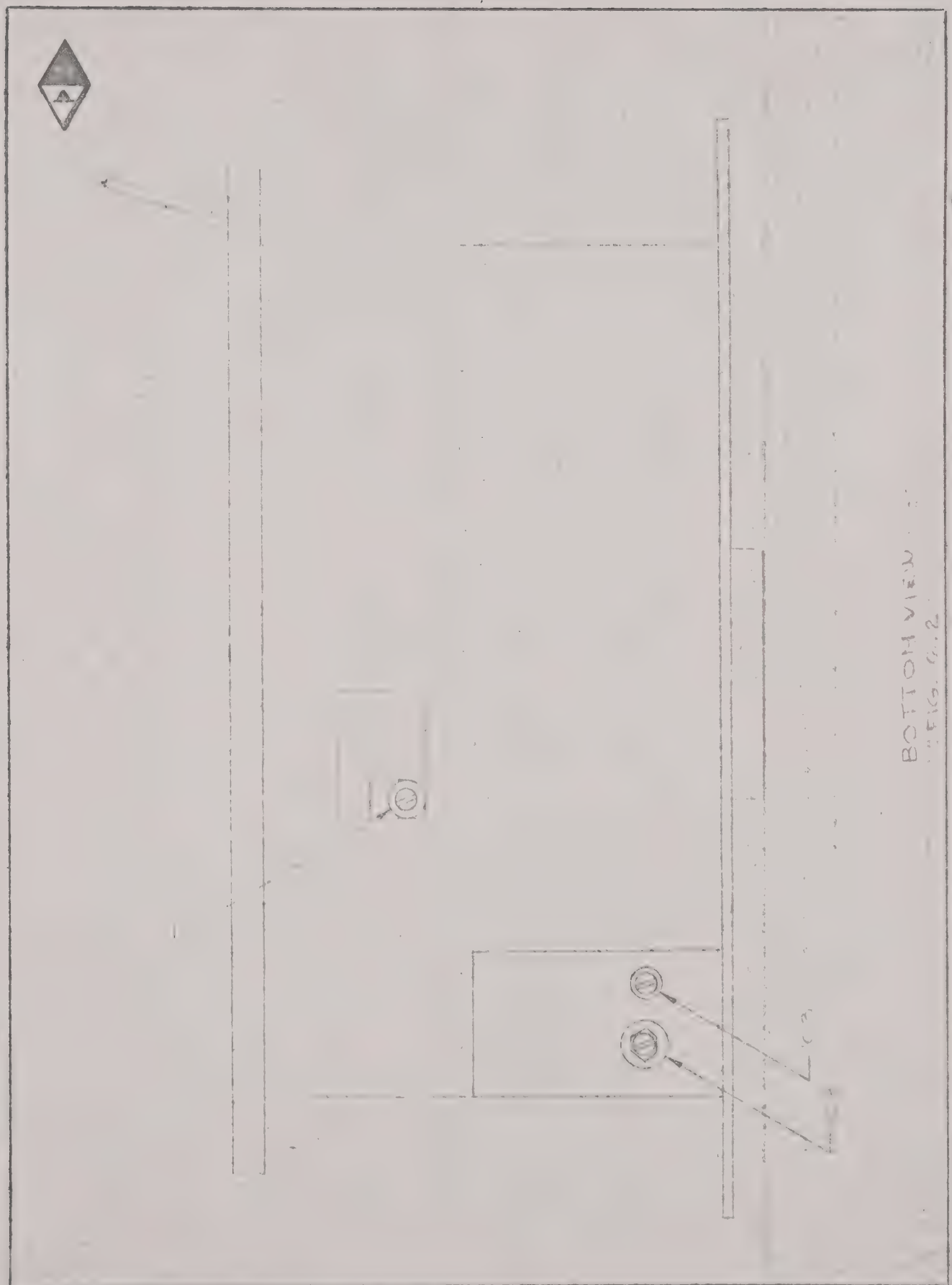

R82-2
R82-1
R18
R26
R72
R47-1
R48-1
R47-2
R48-2
R47-3
R48-3
TOP VIEW
FIG. 6.1


BOTTOM VIEW
FIG. 6.2

REPLACEMENT PARTS LIST

Designation	Description	Source & Part No.*
C1	Capacitor, Paper, .05uf, 1000V	Sprague 160P473010
C3	Capacitor, Variable, 3-12uuf	Erie TS-E
C4,C15,C35	Capacitor, Paper, .047uf, 200V	
C5	Capacitor, Paper, 2.0uf, 200V	Aerovox P82ZK10G
C5A,C12,C16	Capacitor, Paper, 1.0uf, 200V	
C6-2,-1,-3	See Frequency Table on Schematic	
C7A,B,C,D	Capacitor, Electrolytic, 4x10uf, 450V	
C8	Capacitor, Paper, .47uf, 400V	
C9	Capacitor, Electrolytic, 500uf, 6V	
C10	Capacitor, Electrolytic, 5uf, 50V	
C11	Capacitor, Paper, .25uf, 400V	
C17-1,-2,-3 C13,C38	See Frequency Table on Schematic	
C18,C24,C23	Capacitor, Paper, .1uf, 400V	
C19,C25,C42	Capacitor, Paper, .047uf, 400V	
C20,C26	Capacitor, Electrolytic, 5uf, 50V	
C21-1,-2,-3	Capacitor, See Frequency Table on Schematic	
C22-1,-2,-3	Capacitor, See Frequency Table on Schematic	
C27A,B,C	Capacitor, Electrolytic, 3 x 20uf, 450V	

*Part Number given only when no commercial equivalents in size or function are available.

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Designation	Description	Source & Part No.*
C28,C29	Capacitor, Electrolytic, 1000uf, 15V	
C31,C32	Capacitor, Electrolytic, 50uf, 6V	
C33	Capacitor, Variable, 7-45uuf	Erie TS-E
C34	Capacitor, Paper, .033uf, 400V	
C39	Capacitor, Electrolytic, 2 x 30uf, 250V	
C41	Capacitor, Paper, .01uf, 200V	
C43	Capacitor, Paper, .1uf, 200V	
R3	Resistor, Variable, WW, 10K, 2W	
R4,R36,R4A	Resistor, Comp., 1.2M, 1/2W, 10%	
R5,R17,R37, R5A	Resistor, Comp., 1.5K, 1/2W, 10%	
R6,R6A,R38, R40,R76,R27, R28	Resistor, Comp., 47K, 1/2W, 10%	
R7	Resistor, Power, 12 ohm, 3W, 5%	Dale RS-2
R8	Resistor, Comp., 15K, 1/2W, 10%	
R15,R20	Resistor, Comp., 680K, 1/2W, 10%	
R16,R63	Resistor, Comp., 220K, 1/2W, 10%	
R18,R72	Resistor, Variable, WW, 50 ohm, 2W	
R19	Resistor, Comp., 1 Meg, 1/2W, 10%	
R21,R44,R45 R54,R58,R60	Resistor, Comp., 470K, 1/2W, 10%	
R22	Resistor, Comp., 270K, 1/2W, 10%	

*Part number given only when no commercial equivalents in size or function are available

9/23/65

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Designation	Description	Source & Part No.*
R23,R39-1,-2 -3,R78	Resistor, Comp., 10K, 1/2W, 10%	
R24	Resistor, Comp., 27K, 1W, 10%	
R25	Resistor, Comp., 75K, 1/2W, 5%	
R26	Resistor, Comp., Variable, 50K,2w	Allen Bradley JA2L040S503UC
R29,R30,R31 R32	Resistor, Comp., 2.2K, 1/2W, 5%	
R41,R56, R83-1,-2,-3	Resistor, Comp., 4.7K, 1/2W, 10%	
R42,R33	See Frequency Table on Schematic	
R43,R57,R77	Resistor, Comp., 150K, 1/2W, 10%	
R46,R59	Resistor, Comp., 820 ohms, 1/2W, 10%	
R47-1,-2,-3 R48-1,-2,-3 R82-1	Resistor, Variable, WW, 4K, 2W	
R49,R50	Resistor, Comp., 1.5K, 1/2W, 10%	
R52, R53	Resistor, D.C., 39K, 1/2W, 1%	
R55,R70,R86	Resistor, Comp., 470 ohms, 1/2W, 10%	
R61	Resistor, Power, 7K, 5W, 5%	
R62,R66	Resistor, Power, 15K, 5W, 5%	
R64	Resistor, Comp., 100K, 1/2W, 10%	
R65	Resistor, Comp., 470 ohms, 2W, 10%	
R67,R67A	Resistor, Comp., 5.1K, 1/2W, 10%	

* Part number given only when no commercial equivalents in size or function are available.

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Designation	Description	Source & Part No.*
R68**	Resistor, Comp., 5.1K, 1/2W, 10%	
R69	Resistor, Power, 5 ohms, 3W, 5%	Dale RS-2
R71-1,-2,-3	Resistor, Variable, WW, 50K, 2W	
R73	Resistor, Comp., 100 ohms, 1/2W, 10%	
R88	Resistor, Comp., 51K, 1/2W, 10%	
V1	Tube, 12AT7	
V2,V8	Tube, 6AU6A	
V3	Tube, 6U8A	
V4	Tube, 12AX7	
V5	Tube, 12AU7	
V6	Tube, 6X4	
V7	Tube, 0A2	
CR1,CR2,CR3 CR4,CR6,CR7	Diode, 1N658	
CR5	Selenium Rectifier	Radio Recepter D16N1B1E1G
M1	Meter	NAI #800899
XF1	Fuseholder	Littelfuse 342001

* Part number given only when no commercial equivalents in size or function are available.

** Nominal value, chosen for optimum performance at factory

*** In the event that R51 is replaced in instruments up to s/n 4000, the Phase Dial must also be replaced. Kit # is B500104/B117-2.000-39.

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Designation	Description	Source & Part No.*
F1	Fuse, 1 amp.	Littelfuse 312001
I1	Pilot Light, 6.3V	
I2	Overload Lamp, NE-51	
XI1	Lampholder	Dialco 810B-112
XI2	Lampholder	Dialco 810B-117
	Phase Angle Dial Assembly	NAI #B-500104
R51***	Resistor, Variable, 50K, WW, 2W	NAI B117-2.000-39
	Binding Post, Red	Grayhill 29-1R
	Binding Post, Black	Grayhill 29-1B
	Terminal Mount	Grayhill 2911-1
S4	Function Switch Assembly	NAI #500025
S3	Range Switch Assembly	NAI #500101
S1	Toggle Switch (SPST)	C.H. 8280K15
	Knob, Bar	Acton Lab KN-1P
	Knob, Ref. Adj.	Acton Lab KN-1
T1	Transformer, Power	NAI #200874
T2,T3	Transformer, Driver	NAI #800549
T4,T5	See Frequency Table on Schematic	
T6	Transformer, Signal Isol. (Optional)	NAI B117-2.000-30
T7	Transformer, Reference Isol. (Opt.)	NAI 800050

* Part number given only when no commercial equivalents in size or function are available.

** Nominal value, chosen for optimum performance at factory.

*** In the event that R51 is replaced in instruments up to s/n 4000, the Phase Dial must also be replaced. The Kit no. is B 500104/B117-2.000-39.

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SECTION VII

TROUBLE ANALYSIS CHARTS FOR VM-204

TROUBLE	PROBABLE CAUSE	REMEDY
Equipment fails to operate when turned on. Power lamp I1 does not glow. Filament of tube V3, V4, V5, V6, and /or V8 does not glow.	No power input	Check power input at terminal 1 and 2, primary winding of power transformer T1.
	Fuse F1 defective	Replace fuse F1
	Power lamp I1 defective	Replace power lamp I1.
	Tube V3, V4, V5, V6, and/or V8 defective	Replace defective tube (s)
	On-Off switch S1 defective	Replace On-Off Switch S1
	Power Transformer T1 defective	Replace power transformer T1.
	Low (or no) filament voltage on V3, V4, V5, V6 and/or V8.	Check for 6.3 volts A.C. at terminals 3 and 4, secondary winding of power transformer T1.
Power lamp I1 glows. Filament of tube V1 and/or V2 does not glow	Tube V1 and/or V2 defective	Replace defective tubes(s)
	Bridge rectifier CR5 defective	Replace selenium bridge rectifier
	Resistor R68 defective	Replace defective capacitor.
	Capacitor C28 defective	Replace capacitor C28.

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TROUBLE	PROBABLY CAUSE	REMEDY
Power lamp I1 glows. Filament of tube V1 does not glow, V2 does glow.	Tube V1 defective	Replace V1
	Capacitor C29 defective	Replace capacitor C29
B+ voltage regulation at tubes V1 and V2. Voltage at capacitor C7D does not read 110 volts	Tube V7 defective	Replace tube V7
	Resistor R62 defective	Replace resistor R62
	Capacitor C7 defective	Replace Capacitor C7.
Overload lamp I2 does not glow with input signal of 5 times overload	Low (or no) amplification from tube V1, V2, and/or V3.	Check voltage at junction of resistor R78 and capacitor C7D.
	Overload lamp I2 defective	Replace overload lamp I2.
	Potentiometer R26 defective	Replace potentiometer R26 .
	Filter T4 defective	Replace filter T4.
	Capacitor C11, C4, CR6, CR7, C43, C42, and/or resistors R104, R25 defective	Replace defective components.
Meter M1 reads zero with input signal of 0.1 to 10 volts; voltage readings and tubes check satisfactorily.	Voltmeter M1 defective	Replace meter M1.
	Capacitor C12 defective	Replace capacitor C12.

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CAUTION

High voltage exists at several points in the instrument. Normal precautions consistent with good practice should be taken to reduce shock hazard.

A potential shock hazard exists when ungrounded power source or ungrounded case operation is employed. Persons operating the instrument should be made aware of and take precautions against this condition.

North Atlantic Industries, Inc. cannot be held responsible for damage to person or property in the process of or as a result of maintenance, calibration, or setting up of the instrument.

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WARRANTY

North Atlantic Industries, Inc. warrants its products against defects in material and workmanship for one year from the date of the original shipment. Our liability is limited to repairing or replacing products (except fuses and electron tubes) which prove to be defective during the warranty period.

North Atlantic Industries, Inc. is not liable for consequential damages or for any damage or injury to persons or property resulting from the operation or application of any of its equipment.

Warranty is voided if there is evidence that the product has been operated beyond its design range, improperly maintained, or physically mistreated.

In the event of a malfunction in a product under warranty, the purchaser should notify his local Sales Representative or the Sales Department of North Atlantic Industries, Inc. giving full details of the defect and providing the model and serial number of the instrument. Service data or shipping instructions will be forwarded promptly. There is no charge for warranty repair of products, except transportation charges.

North Atlantic Industries, Inc. reserves the right to make changes and improvements in its products without any liability for incorporating such changes or improvements in any products previously sold.

No other warranty expressed or implied is offered other than the foregoing.

Estimates of charges for out of warranty repairs or other service work will be supplied before work begins. Out of warranty repairs will only be made following the receipt of purchaser's authorization of applicable charges.

Claims for Damage in Shipment

The purchaser should inspect and functionally test the product in accordance with the instruction manual as soon as it is received. If the product is damaged in any way, including concealed damage, a claim should be filed immediately with the carrier, or, if insured separately, with the purchaser's insurance company.

(turn over for Shipping Instructions)

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Shipping

On products to be returned under warranty, await receipt of shipping instructions, then forward the instrument prepaid to the destination indicated. The original shipping containers with their appropriate blocking and isolating material is the preferred method of packaging. Any other suitably strong container may be used providing the product is wrapped in heavy paper or a plastic bag and surrounded with at least four inches of shock absorbing material to cushion firmly, preventing movement inside the container.

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WARRANTY REGISTRATION

Please complete and mail this Warranty Registration Card without delay. Placing this Registration on file with our Service Department will assure that you receive applicable service data as issued. No postage is required. (Mailed on_____ by_____)

WARRANTY REGISTRATION

Date _____

Please register _____

Model No. _____ Serial No. _____

under the terms of the warranty stated in this Instruction Manual.

Name _____

Title _____ Dept. _____

Company _____

Address _____

City _____ State _____ ZIP _____

Calibration and maintenance responsibility has been assigned to the following person and/or department. Address applicable service data to (if same as above, please state):

Name _____

Title _____ Dept. _____

For our information please indicate:

Condition of instrument on receipt _____

Application _____

Will the instrument be: resold as part of a system? _____

maintained as company equipment? _____

SERVICE INFORMATION

This card is provided to aid you in obtaining prompt assistance with questions you may have regarding operation, calibration, maintenance or service parts for your North Atlantic instrument. State information desired and mail. No postage is required.

SERVICE INFORMATION REQUEST

Instrument _____

Model No. _____ Serial No. _____

We require the following service information: _____

_____

_____

_____

_____

Name _____ Title _____

Company _____ Dept. _____

Address _____

City _____ State _____ ZIP _____

Phone _____ Ext. _____

SERVICE INFORMATION

This card is provided to aid you in obtaining prompt assistance with questions you may have regarding operation, calibration, maintenance or service parts for your North Atlantic instrument. State information desired and mail. No postage is required.

SERVICE INFORMATION REQUEST

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Model No. _____ Serial No. _____

We require the following service information: _____

_____

_____

_____

_____

Name _____ Title _____

Company _____ Dept. _____

Address _____

City _____ State _____ ZIP _____

Phone _____ Ext. _____

(please send additional Service Information Request cards_____)

No Postage Stamp Necessary If Mailed in the United States

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BUSINESS REPLY MAIL

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industries, inc.

200 TERMINAL DRIVE,

PLAINVIEW, N. Y. 11803

APPLICATION NOTES

FOR

SERIES 200

PHASE ANGLE VOLTMETERS

The North Atlantic Industries Series 200 Phase Angle Voltmeter is a truly unique, multifunctional instrument which will function as a sensitive voltmeter, a phase angle meter, a meter measuring in-phase signals (E cos θ), and quadrature signals (E sin θ), a phase sensitive null indicator, an impedance meter and a power factor meter.

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PHASE ANGLE VOLTMETER

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I-INTRODUCTION

The following notes will acquaint the user of the 200 Series Phase Angle Voltmeter with the many ways in which these versatile instruments can be used.

By virtue of the instruments ability to measure the two basic characteristics of any signal, namely magnitude and phase angle, measurements are now possible which previously either required extensive associated equipment or could not be made at all.

The principle of operation is illustrated in Figure 1.

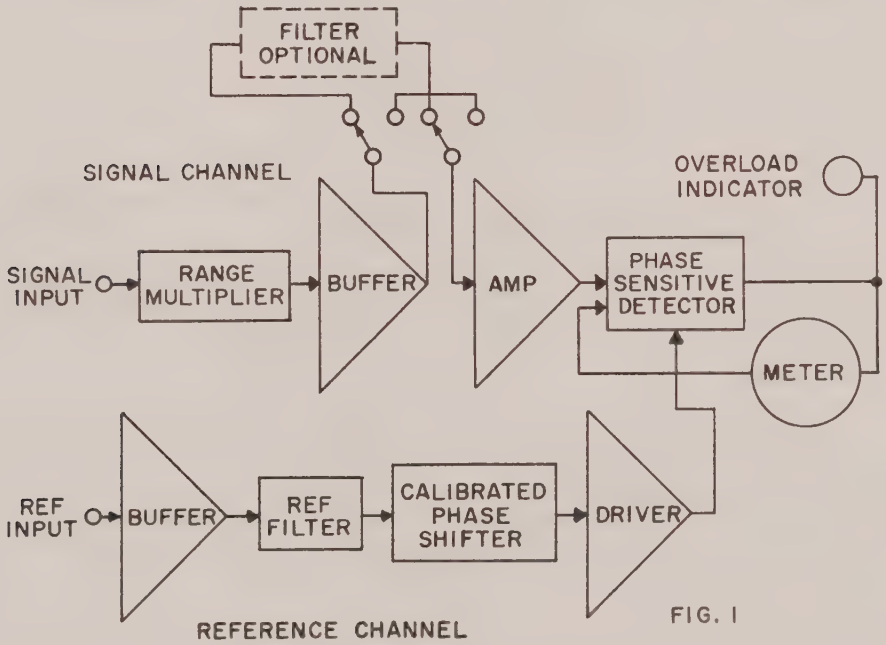


FIG. 1

An input signal is first attenuated by the range multiplier. The high gain amplifier drives a phase sensitive detector which in turn drives the indicating meter. The meter output is recombined to form an a.c. signal which is fed back to the amplifier input thus making the instrument independent of diode characteristics and tube ageing. A reference signal is also amplified and its phase angle shifted by the calibrated phase shifter. This signal driving the phase sensitive detector results in the phase angle characteristics shown in Figures 5 and 6.

The sections to follow describe the many ways in which this instrument is being used. Block diagrams illustrate typical measuring set ups.

II-GENERAL NOTES ON GROUNDING TECHNIQUES

Successful measurement with any high input impedance voltmeter is dependent upon the elimination of all unwanted or extraneous signals from the measurement circuit.

The most common sources for extraneous signals are the following:

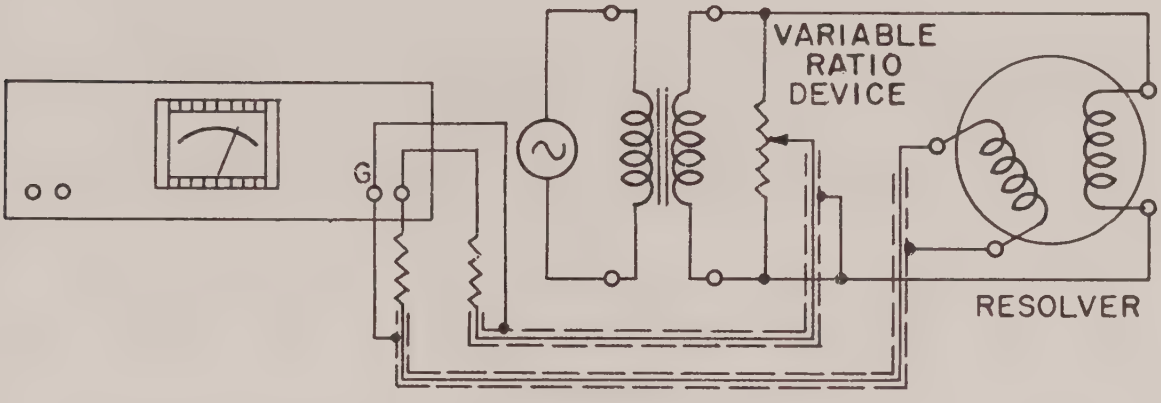
(a) Internal noise
(b) Electrostatic pickup
(c) Inductive pickup
(d) Common Ground Runs

Internal noise has been minimized by design and is equivalent to less than 5 microvolts for a high impedance circuit (1.0 megohm).

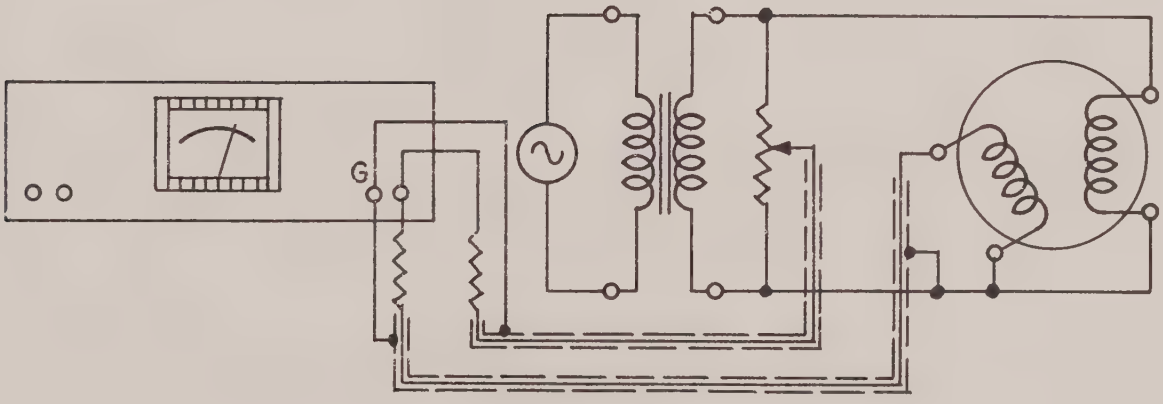
Electrostatic pickup, frequently a problem in high impedance circuits, is easily eliminated by shielded cable or twisting leads, one of which is at ground potential. Care must be taken however to avoid loading the signal source by the by the cable capacitance.

Inductive pickup is generally less often encountered than electrostatic pick-up and possibly for that reason methods for minimizing it are not frequently employed. Both twisted and shielded leads are effective in reducing this form of pickup because they minimize the effective area through which extraneous electromagnetic flux can pass. This is true in the case of a shielded lead, only if the shield, for example, is the return circuit for the signal.

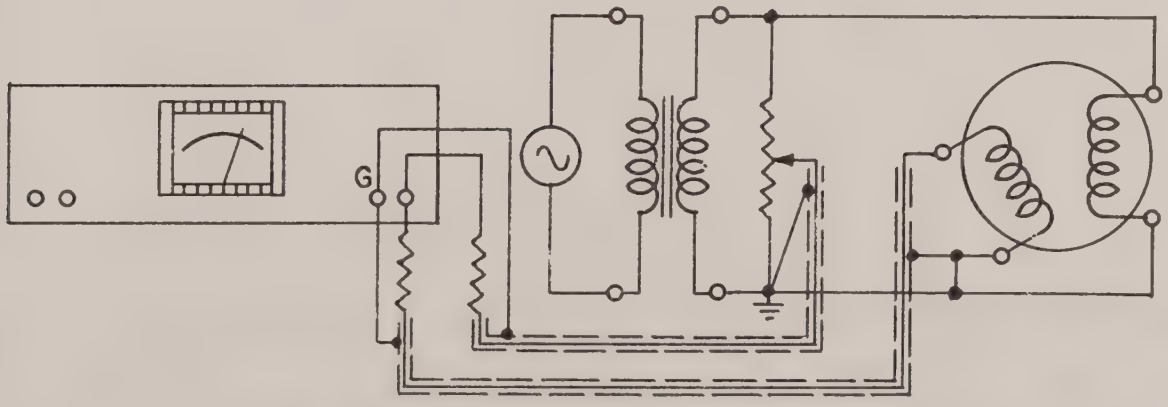
Inductive pickup in ground leads can and does occur with multiple point grounding systems. The effect of these ground loops frequently can be reduced by bundling cables together, again so as to minimize loop areas. A better method is to eliminate the ground loops altogether especially those in the signal system or that portion of a circuit where a measurement is being made. Fig. 2 shows several workable methods for using the voltmeter as a phase sensitive null detector when making transformation measurements. All methods can be made to work by minimizing stray fields and bundling cables together. However, Figure 2A is the most advantageous arrangement and is not at all critical to lead runs. Figures 2B and 2C both have loops which can be potential trouble spots. Note also that grounds other than those shown in Figure 2 can exist due to chassis contact, line cord ground and reference grounds. All must be considered when setting up the measuring system.



(a)—GOOD, NO LOOPS



(b)—ONE LOOP, PICK-UP POSSIBLE



(c)—POOR—ONE SIGNAL LOOP AND ONE GROUND LOOP

FIG. 2—RATIOMETER WITH SERIES SUMMING

Common Ground Runs are sources of extraneous signals by virtue of voltage drops in the voltmeter input which arise from ground current other than the signal ground current. Figure 3 is a sketch of a typical arrangement wherein the power ground lead is in part that of the shield on the signal input. A portion of the load current as well as power supply leakage current to ground go through the voltmeter input cable. The voltage drop in the length of common ground is measured in addition to the signal.

Figure 3 also illustrates the internal grounding arrangement. The fact that there are four places in which a ground can be made could mean that isolation transformers are required somewhere in the measuring circuit.

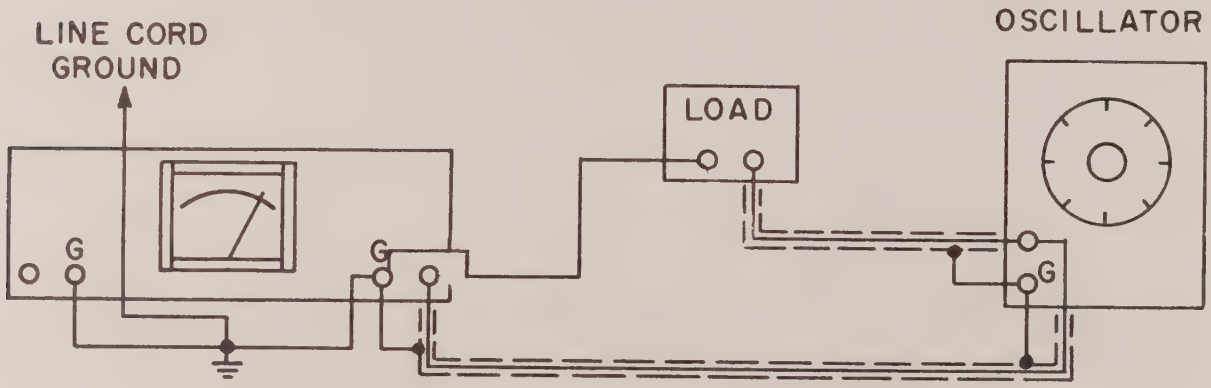


FIG. 3

III-PHASE CHARACTERISTIC

The response of the Phase Angle Voltmeter to the fundamental frequency is given by:

(1) $E_{meter} = E_{rms} \times \cos \theta$

where E_{meter} = voltage read on the meter

E_{rms} = rms value of the input sine wave

θ = angle between the reference and signal input (phase shifter at zero degrees)

Response to even order harmonics is theoretically zero, while odd harmonic response varies inversely with the order of the harmonic.

For example, for the 3rd harmonic equation (1) becomes:

$$E_{meter} = \frac{E_{rms\ (3rd\ harmonic)} \times \cos \theta'}{3}$$

where θ' is the phase angle of the 3rd harmonic with respect to the reference.

Actually response to harmonics departs from equation (2) for a number of reasons. Since calibration of the instrument is at the fundamental frequency, measurements at frequencies other than the fundamental frequency will be somewhat in error.

For instruments having selective filters in the signal and reference channels, harmonic response will in all cases be more than 55 db down. Table I shows typical measured responses. The values shown with filters actually are the sum of the column I data and the filter characteristic.

TABLE I

	RESPONSE SIGNAL	
	No Signal Filter	With Signal Filter
FUND (400 cps)	0 db	0 db
2nd Har	-55 db	> -55 db
3rd Har	-9.5 db	> -55 db
4th Har	-55 db	> -55 db
5th Har	-14 db	> -55 db

Measurements of phase angle using equation (1) are easily accomplished with good accuracy using the set-up shown in Figure 4. The actual phase characteristic used in the measurement is E sin θ for purpose of convenience. The procedure is to adjust accurately the $\theta = 90$ deg. and the $\theta = 0$ deg. point. Measurement then will be a voltage which can be directly translated into degrees using the curves of Figures 5 and 6.

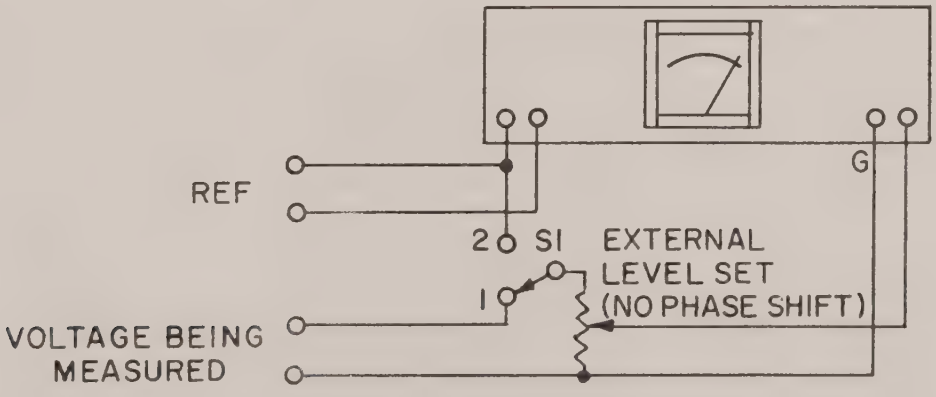


FIG. 4

The step-by-step procedure is:

1. Set reference level to red line value.

2. With meter in "STD VTVM" position and external switch S1 in position 1, select a convenient range and adjust the signal level for full scale deflection. This will insure on-scale readings. (Note: Any external level set should be sufficiently low in resistance so as not to introduce phase shift error.

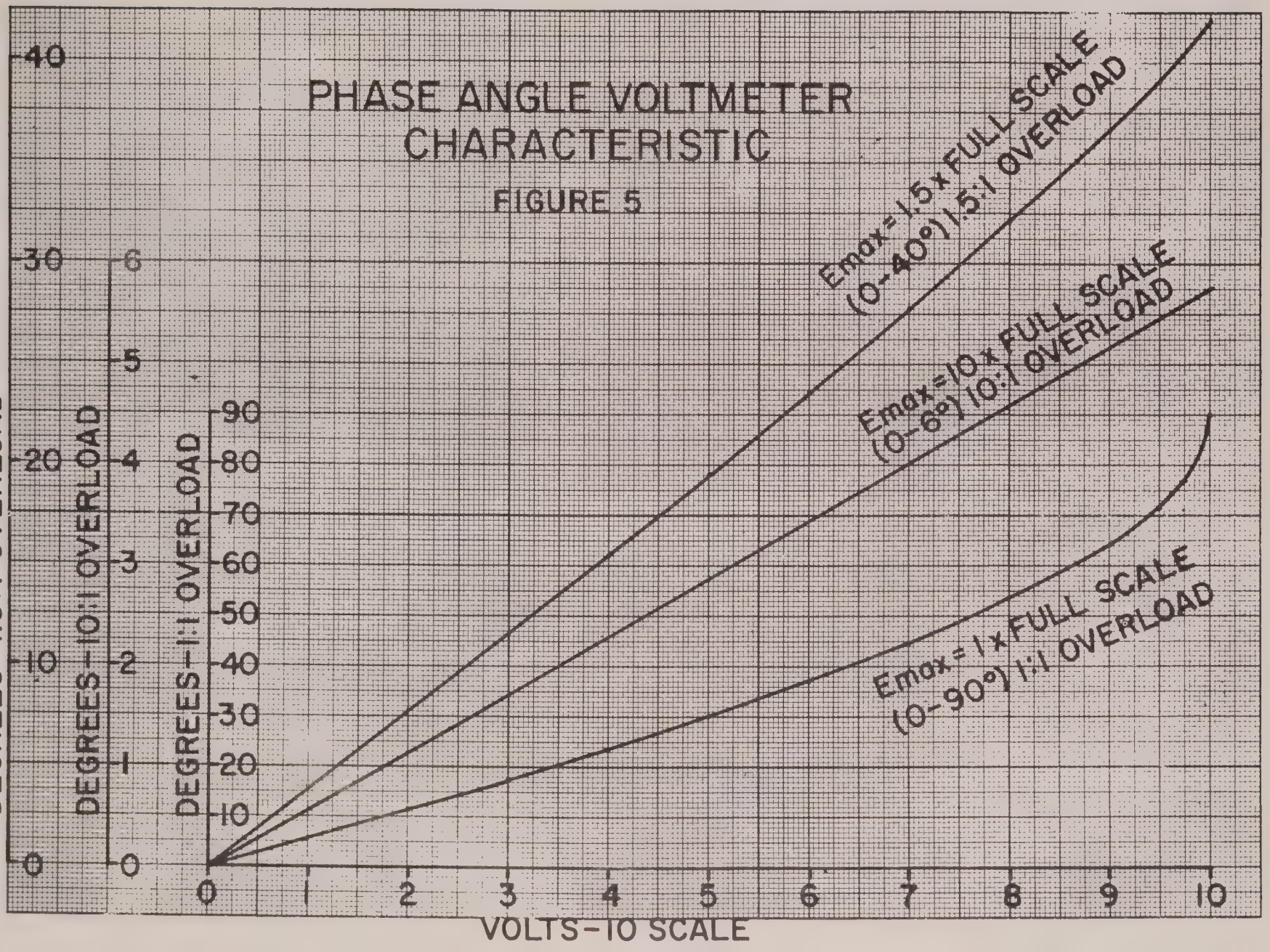
3. Next switch the reference into the signal channel by switching S1 to position 2 and adjust using the same external level control for full scale deflection. Switch the instrument to the "PHASE ANGLE VTVM" function and adjust the phase shift dial for zero meter reading. This establishes the $\theta = 0$ deg. point or quadrature null point. NOTE: FOR MAXIMUM ACCURACY THIS POINT SHOULD BE RESET WHENEVER THE SCALE IS CHANGED.

4. Return the switch S1 to the signal input and readjust the full scale level with the instrument set as "STD VTVM". This establishes the $\theta = 90$ deg. point. (E maximum).

5. Switch back to the "PHASE ANGLE VTVM" position used in (3) above and read the meter. Enter the curves of Figure 5 or 6 to read degrees.

Any full scale range in degrees can be used even down to -6°-0-$+6^{\circ}$ depending upon the full scale limits. For example, if the full scale 90 degree point is set on the 1.0 volt scale and the zero point on the 3.0 volt scale, then the 3.0 volt scale will cover a range of from -17.4 deg.-0- +17.4 deg. Table II summarizes typical set-ups and Figures 5 and 6 show curves which can easily be used to convert voltage measurements to degrees. These curves are actually arcsin functions. The angle can also be derived by direct computation from the voltage readings.

Errors in using this type of measurement will be a function of the scale used and the angle. In addition, for large ratios of maximum voltage to full scale values being used, saturation for a portion of each cycle can occur and will result in a small scale error. Obviously this condition is a function of reference level and for that reason a level of twice the red line value is recommended when using this techique.


PHASE ANGLE VOLTMETER
CHARACTERISTIC
FIGURE 5
Emax=1.5x FULL SCALE
(0-40°) 1.5:1 OVERLOAD
Emax=10x FULL SCALE
(0-6°) 10:1 OVERLOAD
Emax=1x FULL SCALE
(0-90°) 1:1 OVERLOAD
DEGREES-1.5:1 OVERLOAD
DEGREES-10:1 OVERLOAD
DEGREES-1:1 OVERLOAD
VOLTS-10 SCALE
0
10
20
30
40
1
2
3
4
5
6
7
8
9
10
60
50
70
80
90

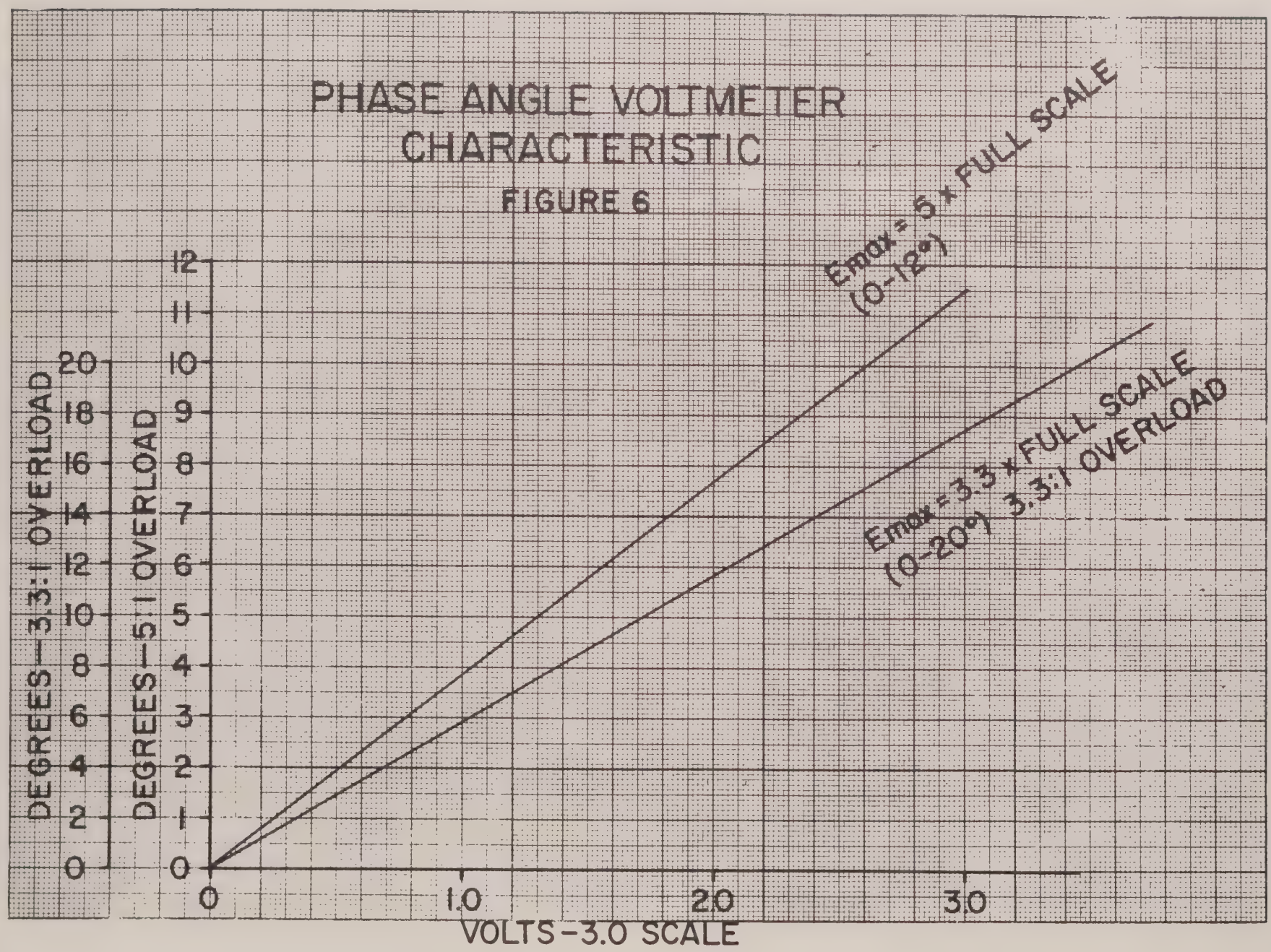

PHASE ANGLE VOLTMETER
CHARACTERISTIC
FIGURE 6
Emax = 5 x FULL SCALE
(0-12°)
Emax = 3.3 x FULL SCALE
(0-20°) 3.3:1 OVERLOAD
DEGREES—3.3:1 OVERLOAD
DEGREES—5:1 OVERLOAD
0
2
4
6
8
10
12
14
16
18
20
0
1
2
3
4
5
6
7
8
9
10
11
12
0
1.0
2.0
3.0
VOLTS—3.0 SCALE

TABLE II

Max. Voltage	Scale for meas. deg.	Full Scale Overload Ratio	Degree Range	Max. Error 3%	Figure
1.0	1.0	1:1	∠ 90	2.7 deg.	5
1.0	.3	3.3:1	∠ 19.5	0.6	6
1.0	.1	10:1*	∠ 5.7	.2*	5
1.5	1.0	1.5:1	∠ 41.8	1.3	5
1.5	.3	5:1	∠ 11.5	.33	6

*NOTE: The overload alarm will be lighted when operated under these conditions. Saturation errors exist and for that reason no error rating is made.

High accuracy Phase Angle Measurements to better than .01° can be made using the alternate methods discussed in Section VIII under Small Angle Measurements.

IV-PHASE ANGLE MEASUREMENTS USING CALIBRATED PHASE SHIFTER

The built in calibrated phase shifter can be used to measure phase angle directly simply by shifting the reference by an amount equal to the phase angle being measured so as to produce a maximum meter reading in accordance with equation (1). Precise determination of the maximum point is difficult due to the zero slope of the phase characteristic at $\theta = 0$ deg. To avoid this difficulty, the instrument is equipped with four scales 90 degrees apart. Thus, by simply switching the reference 90 degrees the phase shifter dial can be readily set to a zero point on the meter and then by switching back to the original quadrant the unknown phase angle can be read.

This procedure allows the measurement of phase angles from 0 to 360 degrees. Ambiguity which exists for two quadrants is easily removed by adding 180 degrees to the dial reading if a negative maximum (meter deflection to the LEFT) is used for the measurement. For positive maximums (meter deflections to the RIGHT) the dial scales apply directly.

V-MEASUREMENT OF QUADRATURE AND IN-PHASE COMPONENTS OF A SIGNAL

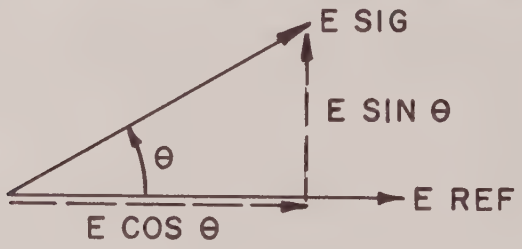


FIG. 7

The quadrature and in-phase components of a signal are defined in accordance with the diagram of Figure 7 as:

In-phase component = E cos θ

Quadrature Component = E sin θ

Measurement of the in-phase component is made by placing the Phase Angle Dial at zero degrees and reading the meter directly. This voltage will be E cos θ. (Function Selector must be in one of the PHASE ANGLE VTVM positions). By switching the Function Selector to an adjacent quadrant, the reference is shifted 90 degrees and the meter now reads the quadrature component of voltage E sin θ. For the greatest accuracy in this type of measurement the null or 90 degree point should be calibrated on the scale in which the voltage component is to be read. See the section under PHASE CHARACTERISTIC for a description of this type of adjustment.

VI-MEASUREMENT OF POWER FACTOR AND IMPEDANCE ANGLE

Both power factor and impedance angle are defined as the angle which a current vector makes with the voltage reference. This measurement is conveniently accomplished by means of the set-up shown in Figure 8. The angle is measured as previously discussed.

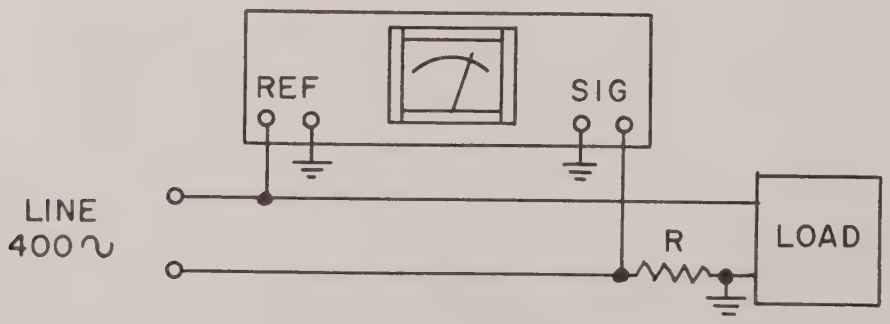


FIG. 8

VII-IMPEDANCE MAGNITUDE

The magnitude of any impedance is measured by using the "STD VTVM" portion of the instrument. Figure 9 illustrates the manner in which the measurements can be made.

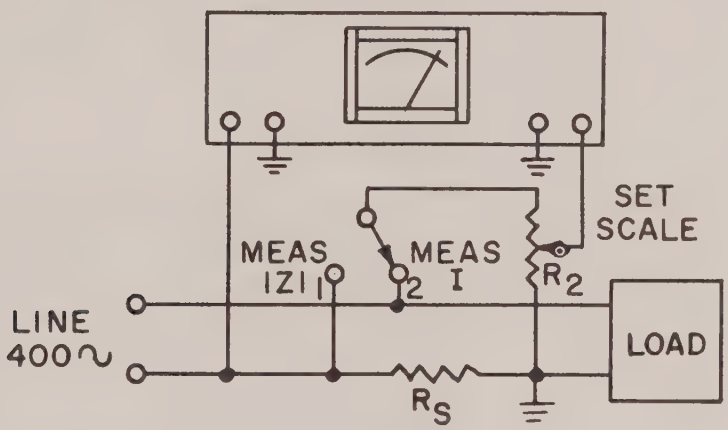


FIG. 9

Using Table III as a guide, a precision ($\leq$ 1%) resistor of convenient size is selected for Rs. With S1 in position 1 for measuring current, adjust the scale set potentiometer to read full scale volts on any 10 scale. Note the actual voltage value. Switch S1 to position 2 for measuring /Z/ and read the meter. This reading will be the impedance magnitude expressed in units of kilohms, ohms, hundreds of ohms, milliohms, etc. depending upon the value of Rs series resistance used per Table III and when divided by the current measurement noted above.

EXAMPLE

Load Impedance = 470K

Rs = 1K

E line = 115 volts

With S1 in position 1 set the level using R2 to a convenient full scale of 10. This might be 0.1 volts. Switching then to position S2 will produce a meter deflection of 47K on the 100K scale (100 volts scale is now 100K per Table III). Dividing this by the current scale of 0.1 will yield 470K. Since the current factor is always set at a multiple of 10, this last correction is simple to accomplish.

TABLE III

Series Resistor	Scale 1 Volt Equals	Current Factor
10K	10K	1/volts
1K	1K	"
100 ohms	100 ohms	"
10 ohms	10 ohms	"
1 ohm	1 ohm	"

Measurement of A.C. Resistance and Reactance

By using the circuit of Figure 9 the real and imaginary components of the impedance can also be measured directly by using the current as a refer-ency and measuring the in-phase and quadrature components of the signal measured with the switch in position 2. The in-phase component will be the A.C. Resistance and the quadrature component will be the reactance with the sign determined as positive for a right hand meter deflection and negative for a left hand deflection.

The following series of block diagrams will illustrate how this instrument can be applied to some of the specific applications noted earlier.

VIII-APPLICATIONS

Precision Ratiometer

In many analogue computer systems the process of multiplication, division, addition and subtraction is accomplished using precision potentiometers, or resistors. Those applications involving extremes of precision must be concerned with the distributed capacitance of the circuit element. Ordinary nulling system, for example, will not permit the manufacture of very precise resistors because of the errors masked by quadrature signals. The circuit of Figure 10 permits precise zeroing of pots or matching and calibration of resistors and potentiometers independent of stray capacitances, or harmonics in the signal source.

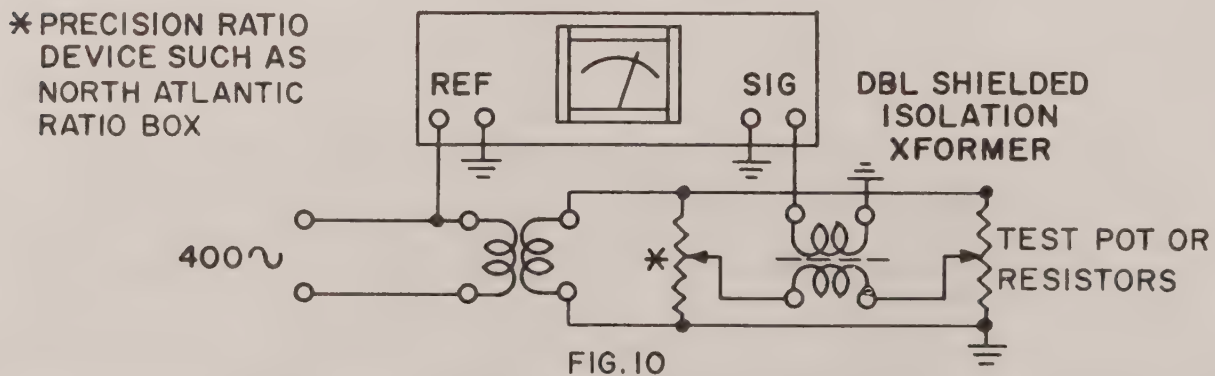


FIG. 10

Two isolation transformers are actually not necessary. If the source is to be isolated then an inexpensive transformer can be used. If the outputs are to be isolated then a low capacitance transformer such as a North Atlantic T-110 should be used. An alternate arrangement would be the circuit of Figure 11, which uses a summing network.

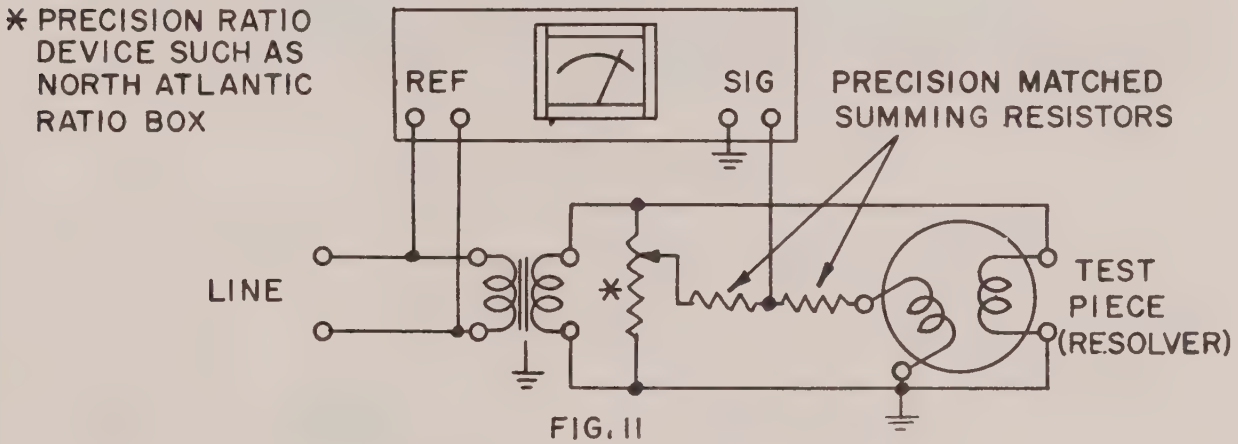


FIG. 11

Transducer Nulling

Applications involving transducers such as differential transformers or E-Coil pickoffs are extremely difficult to zero due to the large residual null voltage composed of signal and harmonics from the source as well as harmonics generated in the transducer. Figure 12 shows a system in which a precise in-phase balance can be achieved in the presence of quadrature and harmonics equal to 10 times the full scale sensitivity used. An order greater accuracy in nulling is easily achieved over conventional nulling circuits.

In addition, phase compensation for servo systems or for purposes of linearity compensation are easily accomplished using variations of this same test set-up.

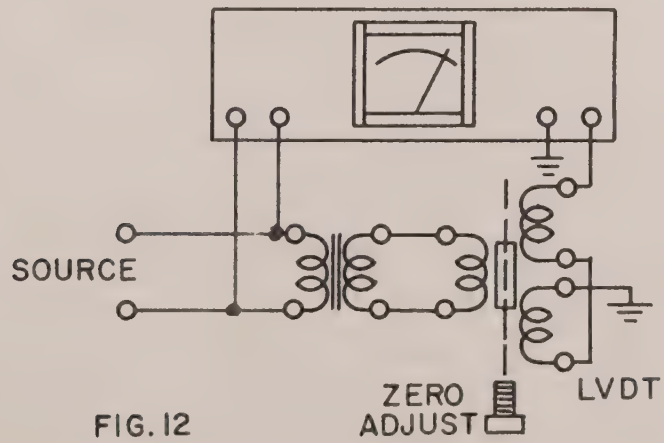


FIG. 12

Synchro Bridge Null Detector

When measuring the electrical errors of synchros, a circuit such as that shown in Figure 13 is used. The phase sensitive characteristics of the Phase Angle Voltmeter as well as the harmonic rejection of the filters and detector makes possible precision nulls unobtainable by conventional instrumentation.

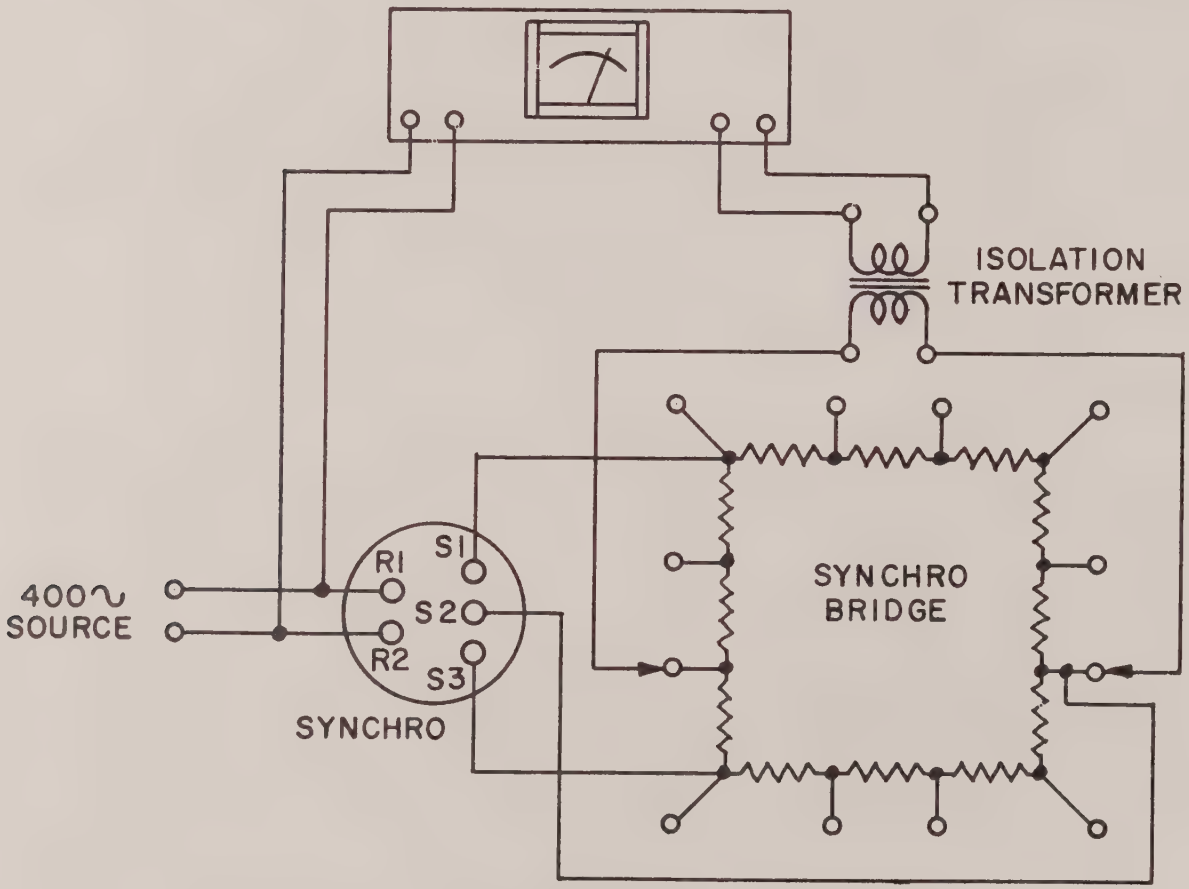


FIG. 13

Magnetic Amplifier and Thyratron Circuit Alignment

Circuits using thyratron power stages or magnetic amplifier stages cannot be monitored using conventional instruments because measurement errors can be prohibitively large due to the chopped wave forms. If the Phase Angle Voltmeter is used to monitor the output of such devices as shown in Figure 14, the task of alignment for maximum torque or output is straight forward since the meter reading is equivalent to motor output.

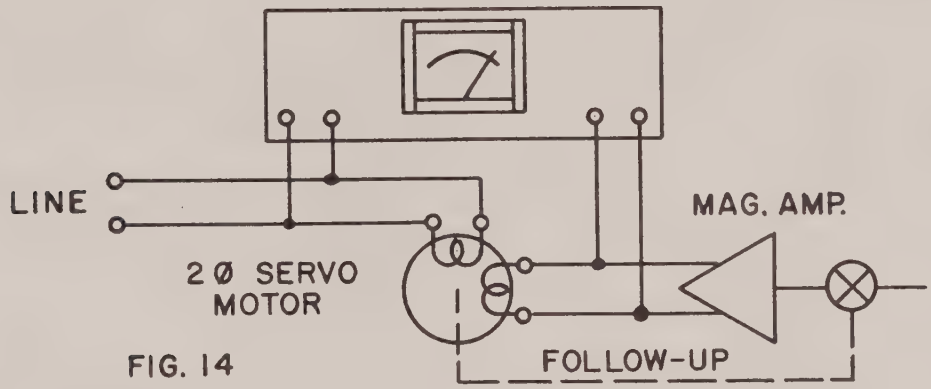


FIG. 14

Carrier Circuits and Amplifiers

Circuits such as those used for phase compensation, summing circuits, amplifiers, etc. must frequently be aligned to reduce quadrature effect to an acceptable minimum and to establish transfer functions at precise values of Phase Angles. Figure 15 is a test set-up used to check the phase angle transfer characteristic of a 400 cps carrier amplifier. Switch, S1, is used to adjust exactly the 90 degree point. A precision of trim to a fraction of a degree can be obtained.

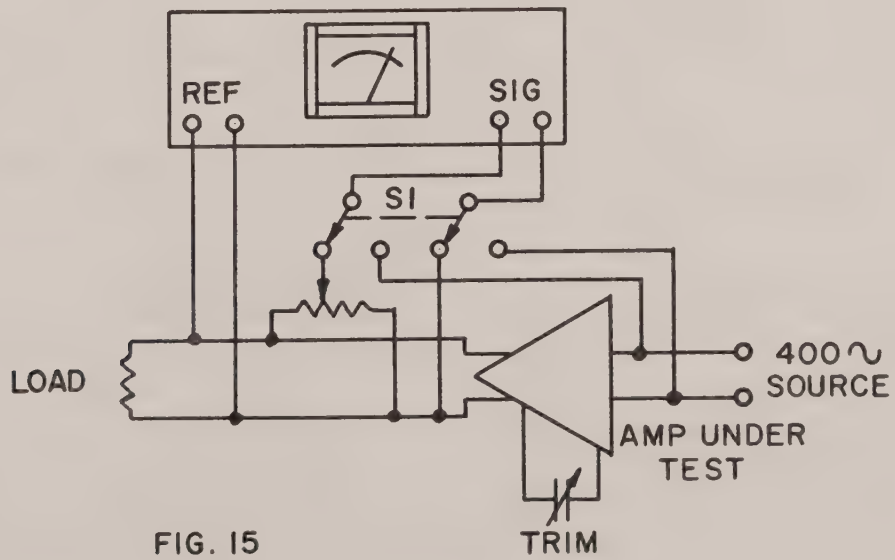


FIG. 15

TRANSFORMATION RATIO

Numerous circuit arrangements are used in making transformation ratio measurements. Two of the most practical are shown in Figure 16 (a) and 16 (b).

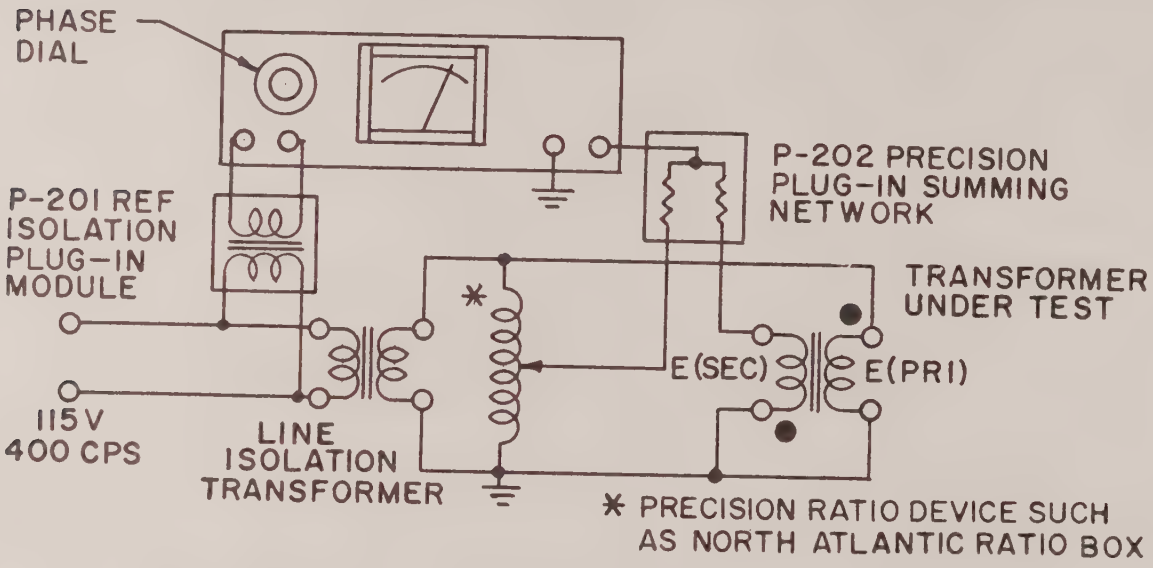


FIGURE 16 (a)

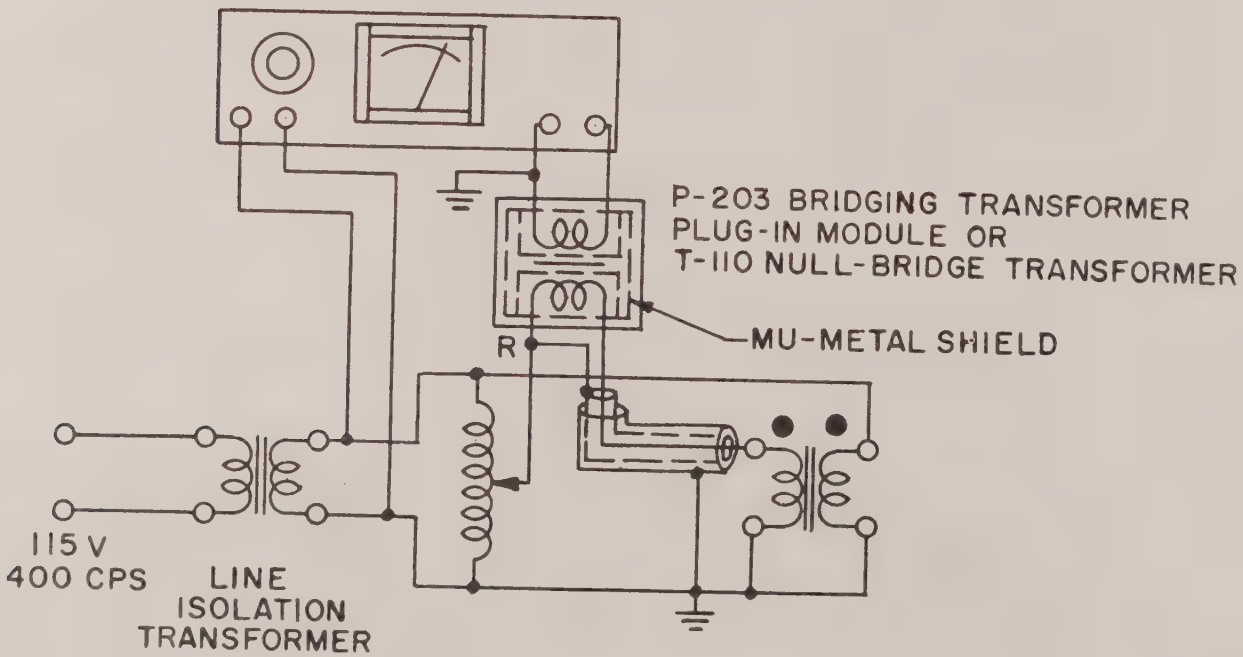


FIGURE 16 (b)

I. SUMMING NETWORK TECHNIQUE

In Figure 16 (a) the output of the test piece is arranged to have a polarity opposite to that of the ratio device. By means of precision summing resistors - available from NORTH ATLANTIC as the P202 PLUG-IN SUMMARY MODULES, the outputs are added. At null the ratio device will then read the in-phase ratio of the item under test. In this particular test set up a line isolation transformer is utilized so as to avoid grounding one side of the line. For illustrative purposes the NORTH ATLANTIC P-201 PLUG-IN REFERENCE ISOLATION MODULE is also shown as providing circuit isolation on the reference input. This feature can also be built into the voltmeter.

In using the circuit of Figure 16 (a) care should be exercised in evaluating the errors which can arise due to loading of the test piece by the summing resistors and inaccurate summing due to test piece source impedance.

Phase angle is easily measured using the technique shown in the following section for small angle measurement. Allowance must be made in this case for the 2:1 change in voltmeter sensitivity resulting from the summing network.

II. BRIDGING TRANSFORMER TECHNIQUE

For greater accuracy, the circuit of Figure 16 (b) has found wide acceptance where the requisite polarity arrangement is feasible. In this case, matching of the test piece output to the ratio device is achieved by using a bridging transformer. A NORTH ATLANTIC P203 BRIDGING TRANSFORMER MODULE is shown, although any good double-shielded isolation transformer with suitable common mode rejection and low input capacitance would suffice.

Measurement errors in Figure 16 (b) can occur due to capacitive loading of the test piece or capacitive coupling of the common mode signal into the secondary. The former can be minimized where shielded cables are used by using the so called "driven shield" technique shown in the figure.

Common mode rejection is a function of the transformer shielding, the impedance level of each input to the transformer and the relative values of these impedances. Each set up must be judged by itself as to its suitability for a particular measurement.

Phase angle again is easily measured using the small angle measuring technique shown in the following section. Here allowance must be made for the bridging transformer transformation ratio (1:1 for the NORTH ATLANTIC P203 MODULE).

Both of the above measuring systems are used to provide a direct reading of in-phase ratio. Transformation ratio is by definition the ratio of the absolute magnitude of the secondary to primary voltage. To obtain "transformation ratio" the "in-phase" ratio must be divided by the cosine of the phase shift angle.

Maximum accuracies for both set-ups require that the phase dial be adjusted to compensate for residual phase shifts arising from the various transformers in the system, etc.. This is conveniently done by stepping the ratio device and adjusting the phase dial to produce zero output when the function selector is in the 90° position. Operation will then be correct when the function selector is returned to the 0° position.

Small Angle Measurements

Small angle measurements to better than .01° can also be made using the set ups of Figure 16. The process consists of making the in-phase null, described in the foregoing, using the precision ratio device. Then, by definition the phase shift angle α is:

$$\alpha = \text{Tan}^{-1} \frac{\text{E Input (quadrature)}}{|\text{E sec}|} = \text{Tan}^{-1} \frac{\text{E Input (quadrature)}}{|\text{E pri}| \times \text{Ratio}}$$

By measuring the magnitude of the secondary voltage and the quadrature component of the input signal, the angle α can be determined.

For Example:

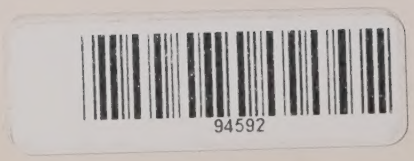
Measured quadrature = 30.0 millivolts

Secondary voltage = 30 volts

$$\alpha = \text{Tan}^{-1} \frac{0.03}{30}$$

$$\cong \frac{0.03}{30} = 0.001 \text{ Rad}$$

$$\equiv 0.001 \times 57.3 = .057 \text{ degrees}$$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